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Articles

A Simulation Model for Evaluating Worldwide Buffer Stocks of Wheat

Shlomo Reutlinger

Stochastic simulation is advocated for quantifying the impact of alternative buffer stock levels and storage policies on stabilizing world wheat supplies and for estimating the corresponding benefits and losses to the world economy, to the storage operation itself, to consumers, and to producers. Illustrative runs of the model show that stock levels which are optimal in terms of direct costs and benefits are likely to be too low to afford satisfactory levels of stabilization. However, buffer stock programs operated with insurance-oriented storage rules could provide satisfactory protection against extreme shortfalls in grain supplies at a reasonably low cost.

Key words: buffer stocks, grain storage, stabilization, stochastic simulation, wheat.

The debate over world food stocks—how much, the rules for accumulation and release, and who should pay—continues to remain high on the agenda of public debate. The economics profession has yet to make a substantial contribution on this important issue of public policy. On the one hand, applied welfare economics has given insights into who gains from stabilization and economists have constructed models to estimate optimum storage levels, where the optima are defined in terms of single narrow economic or financial objectives (see Gustafson; Hueth and Schmitz; Oi; Samuelson 1972; Waugh). On the other hand, some workers have made estimates of the storage levels needed to stabilize supplies without providing a meaningful analysis of costs and benefits (see USDA). Many studies analyze the effect of storage operations on the basis of a probability distribution of production without regard to the sequence of good and bad harvests or else project the storage effects on the basis of a particular past sequence of years (see USDA, UN). All estimates of the effects of storage on the world's food economy are based on aggregate production and consumption data and abstract from spatial and trade constraints.

If not much else, the current public debate over international grain storage levels and rules clearly illustrates that it would be futile to attempt to influence the course of decisions by analyzing any one single dimension of storage effects. There is clearly a distinct concern for maximizing expected benefits (or minimizing expected costs) as well as for increasing price and quantity stability. Equally, if not more importantly, any discussion of national or international storage operations must confront issues arising from the incidence of benefits or losses to consumers and producers (importing and exporting countries). In theory it is possible to resolve the trade-offs between diverse objectives by specifying an appropriate social welfare function. In practice such a specification is an elusive goal for it involves subjective judgments on which a priori agreement among the parties is unlikely to occur.

The approach taken in this study clearly departs from the pursuit of a single optimal solution. A model is used to trace out the implications of several levels of storage activity and storage rules for several objectives. In the interest of providing useful insights on the general orders of magnitude of the impact of storage activities, the model is purposely kept simple. Several shortcomings of the model in terms of the complexity of the decision environment of the real world will be discussed

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This paper is based on a larger research project by the author aimed at specifying country models for evaluating buffer stocks and also draws on a earlier paper by the author (1971). The author is grateful to David Blum for research assistance, to C. J. A. Jansen, and to the anonymous reviewers for their substantial contributions toward improving the clarity of exposition.

and presented as appropriate topics for subsequent research.

The Model

In attempting to estimate worldwide price and consumption fluctuations with and without storage, the world is viewed as one unified market. Fluctuations in world consumption and price are assumed to depend only on fluctuations in world production and the extent of storage activity, i.e., any friction arising from trade constraints or shipping costs which separate regions of production and consumption is disregarded. Much more sophisticated and time-consuming models and data are needed to estimate the effects of buffer stocks in a world of segregated markets.

The model simulates fluctuations in the consumption and price of wheat under various levels of storage and with various storage rules governing the accumulation and release of stocks. World grain production is estimated on the basis of a large random sample drawn from a known probability distribution. Price is determined on the basis of a demand function relating the world price to the quantity of grain available for consumption. In any given year, grain supplies depend on the level of production and the amount of grain put into or taken out of storage.

The level of storage activity is determined by the level of production and the storage rules and is constrained by storage capacity and the amount of grain stored in previous years. The storage rules are as follows. If production is above a prespecified level (and the price below a certain level), the surplus grain is put into storage. If production is below a prespecified level (and the price above a certain level), grain is withdrawn from storage to augment supplies from production up to the prespecified level. The actual amount stored or withdrawn from storage is determined by simulating sequences of annual production levels and inventory levels on the basis of a large sample drawn from the probability distribution of production with prespecified storage capacity. Finally, the probability distribution of consumption and grain prices associated with different levels of worldwide storage capacity is calculated.

Given the estimated quantities and prices which obtain with and without storage, the model estimates the economic and financial

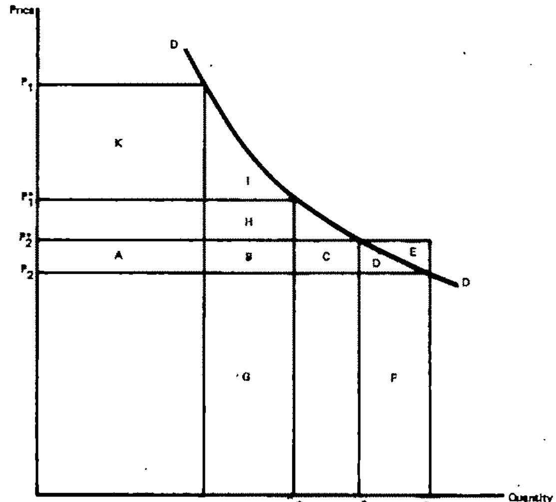

Figure 1. Storage benefits and losses

benefits or losses attributable to storage and the gains or losses experienced by producers and consumers each year. To obtain net variable benefits, variable storage costs are subtracted. The present value of the discounted stream of benefits and losses over a thirty-year period is then calculated. Finally, on the basis of a sample of 300 thirty-year sequences, the expected present value of the economic and financial benefits or costs (the producer and consumer gains or losses) and their respective standard deviations are estimated.

The calculation of annual gains or losses attributable to storage is illustrated in figure 1. The demand curve for grain is represented by DD; Q_2 is the level of production in a year of plenty. A quantity, $Q_2 - Q^*_2$, is placed in storage; Q_1 represents the level of production in a year of poor harvests; $Q^*_1 - Q_1$ is released from storage. In a year of plenty, the prices are P_2 without, and P^*_2 with storage. In a year of poor harvests, the prices are P_1 without and P^*_1 with storage.[1]

The financial (or storage operator's) gains or losses are straightforward. Assuming that purchases for or sales from storage are valued

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[1] A single unique price corresponding with any level of production and storage activity presupposes that the trade can correctly anticipate the actual levels of production and quantities of grain going into or being released from storage. This presupposition implies, among others, that the storage operations are administered by a public authority whose primary objective it is to stabilize prices rather than to maximize profit. In the absence of unique price anticipations, the distribution of benefits (or losses) between consumers, producers, and storage operator could be quite different than those estimated by the model used in this study.

Table 1. Summary of Storage Benefits or Losses

	Benefits (+) and Losses (−)
Year of accumulation of stocks	
Consumer benefits	−A − B − C − D
Producer benefits	A + B + C + D + E
Financial benefits	−F − D − E
Economic benefits	−F − D
Year of release of stocks	
Consumer benefits	K + I
Producer benefits	−K
Financial benefits	G + B + H
Economic benefits	G + B + H + I

at the market price, the cost of grain put into storage is $P^*_2(Q_2 - Q^*_2)$ (designated as areas $F + D + E$ in fig. 1). Similarly the revenue from the grain taken out of storage is $P^*_1(Q^*_1 - Q_1)$ (designated as areas $G + B + H$ in fig. 1). Producer gains or losses are also straightforward. When grain is put into storage, producers sell the same amount of grain but at a higher price. Their gain is $(P^*_2 - P_2)Q_2$ (designated as areas $A + B + C + D + E$ in fig. 1). Similarly, when grain is taken out of storage, producers receive a lower price; their loss is $(P_1 - P^*_1)Q$ (designated as area K in fig. 1).

Consumer gains or losses and, hence, economic gains and losses can be measured in terms of consumer surplus. Consumers' losses are of two kinds when grain is withdrawn from the market. They pay a higher price for the grain which they do consume with or without storage (areas $A + B + C$ in fig. 1), and they are deprived of the amount of grain which is stored. Applying the consumer-surplus concept, the consumer loss due to the decline in consumption is measured by area D in figure 1. Similarly, when grain is withdrawn from storage, consumers experience a cost saving on the grain which they consume with or without storage (designated by area K in fig. 1). The additional grain consumed as a consequence of storage is measured by area I in figure 1.[2]

The benefits (+) or losses (−) which accrue to different groups in any year from storage activities, expressed in terms of the areas designated in figure 1, are summarized in table 1. Consumer benefits, financial benefits (the benefits to the storage operator), and economic benefits are always negative in years when stocks are accumulated and positive in years when grain is released from storage. Producers always gain when grain is put into storage and always lose when grain is released from storage. The present value of variable benefits depends on the difference between gains and losses in years of storage activity, the time elapsed between storage operations, the discount rate and variable storage costs. The present value of total net benefits also depends on the cost of constructing storage facilities.

Data and Parameters

World production is assumed to have a mean value of 350 million metric tons and to vary in the range of 314 to 386 million tons in accordance with a triangular probability distribution.[3] The mean value roughly corresponds with the trend value of production in 1972–73, and the interval on either side of the mean corresponds to approximately 2.5 standard deviations, the value of which (14 million tons) has been estimated on the basis of past deviations about the long-run trend in world wheat production (Steele, table 3).

The function chosen to represent the demand for wheat consists of two linear segments kinked at the point of mean world production. The parameter values of the two linear segments are specified to give a lower price elasticity in the range of short supplies and a higher elasticity in the range of abundant supplies. There are several plausible reasons why this should be a reasonable specification. Observed demand may reflect buying and selling for storage as well as current consumption. Under certain circumstances, private firms and governments may accumulate inventories when supplies are short and dispose of these inventories in times of plenty. When supplies are short and a large proportion of the population lives at the margin of minimally adequate nutrition, governments can be expected to (and actually do) attempt to maintain the consumption of the poorest segments of the population through increased purchases and distribution of food grains on concessional terms. Consequently, the price rises sharply in the face of reduced supplies. On the other hand,

[2] The consumer surplus concept as applied in this paper is widely used in analyzing the impact of trade, taxation and price policies. It is at best an approximation device. For a discussion of the restrictive assumptions underlying the use of the concept and the possible errors, see Samuelson (1963).

[3] The simulation model is currently reprogrammed to accommodate several alternative probability density functions.

when supplies are plentiful and the price comes within the range where it is profitable for wheat to be used in livestock feeding, this addition to the demand for direct consumption tends to increase the demand elasticity. Recent sharp increases in price in response to relatively small reductions in anticipated supplies provides some empirical evidence in support of the hypothesis that demand is very inelastic when supplies are short (UN, p. 6).

The precise demand function used in the initial simulations is as follows:

$$\begin{aligned} p &= 1374.5 - 3.57q \qquad q \leq 350 \\ p &= 541.5 - 1.19q \qquad q > 350, \end{aligned}$$

where p is the price of wheat per ton and q is the quantity in millions of tons. The elasticity at the midpoint of the segment corresponding with short supplies (332 million tons) is -0.15 and that at the midpoint of the segment corresponding with long supplies (368 million tons) is -0.24.[4]

The variable storage cost (loading and unloading, pest control, and electricity) is estimated at \$2 per ton. The discount rate is assumed to be 8%. The present value of the investment in storage silos is assumed to be \$50 per ton of storage capacity. The present cost of constructing new storage facilities is approximately \$150 per ton of capacity. However, due to the existence of a large underutilized capacity, it is assumed that additional investment will be required only to augment and to replace existing capacity and that construction will be spread out over many years.

The basic simulations consider storage capacities of 5, 10, 20, and 30 million tons (30 million tons corresponding roughly to two standard deviations of world production). Storage rule A provides that production in excess of 355 million tons is put into storage (to the extent that there is vacant capacity). When production is less than 345 million tons, grain is released from storage to the extent of the deficit (or to the extent of available stocks in storage). Storage rule B differs from storage rule A in so far as grain is released from storage only when production is less than 335 million tons.

The Effects of Storage Activity

The results presented below are based on simulating production and storage activities for 300 sequences, each consisting of thirty years. The observed frequency distribution of production of a sample of this size closely approximates the postulated probability distribution. Similarly, the sampling error of the expected values and the standard deviations of the estimated variables is small.[5]

Stabilization Effects

Table 2 summarizes the effects of storage activity on the stabilization of consumption and price. Several generalizations are possible. Storage can effectively reduce the probabilities of extreme events. For any given level of storage capacity, rule B gives far better insurance against extreme shortfalls of grain availability for consumption and high prices than rule A. Additional increments of storage capacity result in diminishing marginal reductions of the probability of being caught short.

Benefits and Costs

Table 3 presents the expected present value of benefits (+) or costs (−) over a thirty-year period of storage operations. Several noteworthy conclusions emerge. Storage benefits to the economy are low or negative and rapidly decline or turn negative beyond initial low levels of storage capacity. The reason for this is that, as the storage levels increase, there is less turnover in storage and grain is held for longer periods. The cost of time (interest) increasingly dominates the gross benefits which accrue from buying grain when its value is low and selling it when its value is high. As for the net benefits, the amortization cost per ton rises as the utilization of the storage capacity decreases.

Large benefits accrue to consumers, while producers pay a high price for stabilization. However, these gains and losses reach a plateau, as incremental storage capacity is increasingly less utilized. Moreover, the additional grain is stored for longer periods of time, until ultimately the discounting factor comes to dominate the gains or losses from price changes for consumers (or producers).

[4] As a first approximation, the average price elasticity was assumed to be −0.2, based on the analysis of elasticities by major countries, reported by Rojko.

[5] In estimating the present value over a thirty-year period, stocks in storage in the last year are valued at the expected price. The initial inventory is always assumed to be zero. No attempt was made to establish an optimum sample size. In view of the low computing costs, it was simply decided to use a sample large enough to yield a low sampling error.

Table 2. Probability Distributions of Wheat Consumption and Price

Quantity	Price	Without Storage	Storage Rule A: Storage Capacity (million tons) 10	20	30	Storage Rule B: Storage Capacity (million tons) 10	20	30
(million tons)	($/ton)	Probability (%)						
<324	>219	3.9	1.9	1.2	0.9	1.1	0.5	0.5
324–332	188–219	9.7	6.6	5.7	4.6	6.1	3.1	1.6
332–359	115–188	57.7	72.3	79.3	85.2	70.1	77.6	82.1
359–368	104–115	15.3	10.8	8.3	5.4	12.5	10.8	8.8
>368	<115	13.4	8.4	5.5	3.9	10.2	8.0	7.0
Mean price:	($/ton)	140	137	136	135	138	138	138

The high standard deviations of the present value of the costs of and benefits from storage over a thirty-year period illustrate the risky nature of investment in storage and the folly of using a particular observed sequence of yearly production levels (often of much less than thirty-years' duration) to predict the effects of storage operations. With an 8% discount rate, the sequence of good and bad harvests, particularly during the first years following the investment decisions, can drastically change storage benefits. Even if the expected storage benefits are positive, the chances are high that the investment will not pay off. Could this be a reason for not expecting the private trade to engage in large buffer stock operations?

While, as we have seen earlier, storage rule B gives higher protection against extreme shortfalls, storage rule A leads to greater expected economic benefits (or lower costs). However, even if rule A is followed, buffer stock operations cannot be justified on the grounds of expected economic benefits, except when they are operated on a very small scale, e.g., 5 to 10 million tons (about one-half of the standard deviation).

Since the distribution of gains and losses between consumers and producers is of great significance in assessing the politics of stock policies, it is interesting to note that rule B diminishes this conflict. Since grain is taken out of storage only at times of extreme shortage, grain is stored for long periods. Consequently, the discounting factor comes to dominate producer losses resulting from unfavorable price effects.

The annual, amortized benefits or costs corresponding with the expected present values

Table 3. Present Values of Storage Benefits

Type of Benefit[a]	Storage Rule A: Storage Capacity (million tons) 5	10	20	30	Storage Rule B: Storage Capacity (million tons) 10	20	30
	$ million						
Gross economic benefits	288	392	336	179	−5	−389	−865
	(245)	(424)	(648)	(834)	(451)	(739)	(955)
Net economic benefits	38	−108	−665	−1321	−505	−1389	−2365
Gross financial benefits	194	124	−290	−654	−156	−699	−1271
	(215)	(333)	(450)	(635)	(382)	(623)	(824)
Net financial benefits	−51	−376	−1290	−2154	−656	−1699	−2771
Consumer benefits	4909	8068	11230	12310	−2377	1675	−55
Producer benefits	−4820	−7800	−10604	−11477	−2226	−1365	461
	(2549)	(4323)	(6388)	(7371)	(3367)	(5105)	(6341)
Proportion of capacity utilized	0.156	0.135	0.107	0.090	0.088	0.071	0.061

Note: Values in parentheses are standard deviations.
[a] Gross economic benefits = financial benefits + consumer benefits + producer benefits.
Net benefits = gross benefits − cost of investment in storage facilities.

Table 4. Annual Benefits from Storage Activities

	Storage Rule					
	A			B		
	Storage Capacity (million tons)			Storage Capacity (million tons)		
Type of Benefit	10	20	30	10	20	30
	\$ million					
Gross economic benefits	35	30	16	−0.4	−35	−77
Net economic benefits	−10	−59	−117	−45	−123	−210
Gross financial benefits	11	−26	−58	−14	−62	−113
Net financial benefits	−33	−115	−191	−58	−151	−246
Consumer benefits	716	988	1093	211	149	−5
Producer benefits	−693	−942	−1019	−198	−121	41

reported in table 3 are shown in table 4. To the extent that the benefits are negative and a burden to the world economy, these values can be interpreted as insurance premiums which would need to be paid for achieving stabilization beyond the level at which expected direct gains exceed storage costs.

More stability and less uncertainty can be justified on several grounds. First of all, for grain producers more stable prices can yield more stable incomes, unless the ups and downs of their harvests are positively correlated with world prices. For low income consumers, more stable food grain prices may significantly stabilize effective incomes. Both groups may therefore put a positive value on stabilization of food prices. More significantly, perhaps stabilization might produce positive macroeconomic effects when sharply higher food prices push up negotiated wages, while equivalent reductions in food prices do not lead to wage reductions. Finally, our cost-benefit calculus has not taken into account possible positive output effects and better resource allocation decisions related to more stable food grain price anticipations.

To put the numbers in table 4 into better perspective, it should be noted that the expected total value of world wheat production is \$48 billion (350 million tons × \$140). A 20 million-ton program, operated under rule B and giving a high degree of protection, would have an annual expected cost of \$150 million for the storage operator. Consumers experience an equivalent gain. With average consumption at 350 million tons, consumers could be taxed annually at the rate of 50¢ per ton to cover the loss of the storage operation. This would seem a small premium, for which the consumer would be fully compensated by his expected gains from storage, neglecting completely the benefit he derives from more stable food prices. Producers would have an expected loss of 35¢ per ton. This loss may be a small price to pay for greater price stability.

Cost Effectiveness

Figure 2 illustrates the annual cost (or benefit) of reducing the probability of consumption shortfalls below 332.5 million tons. Without storage, the probability of consumption being less than 332.5 million tons is 13.6%. Several observations may be made. For any given storage level, rule B provides more protection than rule A. The marginal cost of protection increases rapidly for higher rates of protection. For instance, under rule A, at the rate of protection of 4% (i.e., a 9.5% chance instead of a 13.5% chance of having less than 332.5 million tons), an additional 1% of protection would cost approximately \$5 million. At the rate of protection of 9%, an additional 1% of protection would cost \$155 million. For very low rates of protection, rule A is more cost-effective than rule B, but for high rates of protection, rule B is more cost-effective than rule A. For instance, if 9% protection were desired, a storage level of 15 million tons, operated under rule B, could be sustained at an average annual economic cost of 90 million tons. Equivalent protection could be bought under rule A, only with a storage capacity of nearly 50 million tons and at an average annual economic cost of \$240 million.

Sensitivity to Assumed Demand Functions

While the stabilization effect of storage levels and storage rules is unrelated to the parameters of the demand function, the costs and

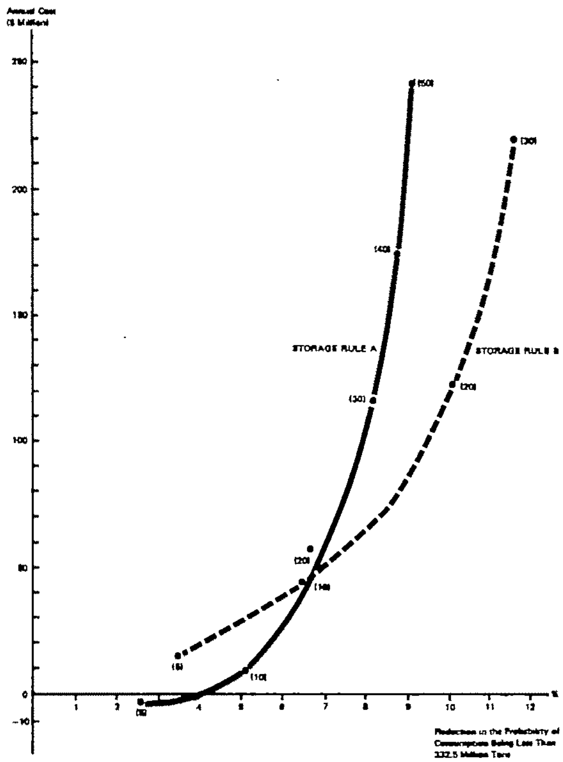

Figure 2. Cost effectiveness of storage operations (storage capacity shown in parentheses)

benefits can be expected to be sensitive to the assumed demand parameters.

Table 5 gives the annual benefits or costs of storage with a demand function which is more elastic for supplies in excess of 350 million tons. The elasticity of the new demand function is −1.0 at the point corresponding to 368 million tons as compared with −0.24 for the initial function. The respective prices at the same point are \$120 and \$103. A more elastic demand function in the range of long supplies does not change the economic and financial benefits very much. However, the gains to consumers and losses to producers are sig-

Table 5. Annual Benefits from Storage Activities with Higher Demand Elasticity for Long Supplies

	Storage Rule					
	A			B		
	Storage Capacity (million tons)			Storage Capacity (million tons)		
Type of Benefit	10	20	30	10	20	30
	\$ million					
Gross economic benefits	10	−3	−24	−16	−59	−107
Net economic benefits	−30	−91	−156	−60	−147	−239
Gross financial benefits	−5	−45	−78	−25	−76	−128
Net financial benefits	−49	−133	−210	−69	−164	−260
Consumer benefits	1206	−1780	2068	576	754	779
Producer benefits	−1188	−1738	−2014	−566	−737	−758

Note: The assumed demand curve: $q < 350, p = 1374.50 - 3.57q$
$q > 350, p = 238.34 - 0.32q$.

Table 6. Annual Benefits of Storage Activities with Lower Demand Elasticity When Supplies Are Short

	Storage Rule					
	A Storage Capacity (million tons)			B Storage Capacity (million tons)		
Type of Benefit	10	20	30	10	20	30
	$ million					
Gross economic benefits	110	136	139	58	42	3
Net economic benefits	66	48	7	14	−46	−129
Gross financial benefits	66	33	4	34	−3	−54
Net financial benefits	22	−55	−128	−10	−91	−186
Consumer benefits	2518	3686	4249	1135	1421	1385
Producer benefits	−2474	−3583	−4114	−1111	−1375	−1329

Note: The assumed demand curve: $q < 350, p = 3003.29 - 8.22q$
$q > 350, p = 541.50 - 1.19q$.

nificantly higher, since withdrawal of grain from the market for storage barely increases the price.

Table 6 shows the results obtained for a demand function which is more inelastic within the range of short supplies. Specifically, the new demand function has an elasticity of −0.10 at the point corresponding to 332 million tons as compared with −0.15 with the initial function. The respective prices at the same point are \$275 and \$189. The economic and financial benefits here turn out to be very sensitive, making it extremely profitable to invest in buffer stocks. But again it is noteworthy that the storage impact on gains and losses by consumers and producers is particularly sensitive to the assumed shape of the demand function.

Food Aid and Food Stocks

In some quarters it is argued that separate food grain stocks should be held to assist poor nations afflicted with unforeseen food shortages. Presumably such stocks would have no adverse effects on producers, provided that without these stocks, there would be that much less food aid. Hence, separate food aid stocks may be politically more palatable.

Alternatively, a policy which aims at assuring food aid at a given level when needed and at the least possible cost, would not separate food aid stocks from other stocks. With such a food aid objective, it would be desirable to hold larger stocks and the value of these stocks would be higher.

As an illustration of the impact of food aid on stocks and vice versa, the results obtained from the simulation using different demand functions can be reinterpreted. The difference between the more inelastic and more elastic demand functions, within the range of less than average production (i.e., 350 million tons), could be assumed to reflect the demand for food aid related to worldwide scarcities of wheat.[6] The difference between the two demand functions is the amount of wheat given as food aid, q_A, i.e.,

$$q_A = -20 + .16p \qquad p > 125$$
$$q_A = 0 \qquad p < 125.$$

With food aid, the price of wheat associated with the worst likely production level (314 million tons) is \$427. In this case the quantity required for food aid is 48 million tons. When world production is 350 million tons or more and the associated price is \$125 or less, the amount of wheat required for food aid is zero.

Table 7 shows the additional gains and losses from storage attributable to the change in the demand function resulting from food aid. The additional economic benefits are sufficient to turn a net loss from storage (without food aid) at almost any level to a net gain for as much as 30 million tons of storage capacity, if operated under rule A. Even more significant, perhaps, is the large effect of storage on consumer gains and producer losses. Without storage, the added demand generated by food aid during times when supplies are short causes steep price rises. Hence, consumers (in the commercial market) register large losses

[6] The demand with aid is $p = 3003 - 8.22q$; the demand without aid is $p = 1374 - 3.57q$. For any given price (above \$125), the respective quantities are $365 - 0.12p$ and $385 - 0.28p$. The difference between the two equations reflects the demand for food aid.

Table 7. Annual Storage Gains and Losses Attributable to Food Aid

	Storage Rule					
	A			B		
	Storage Capacity (million tons)			Storage Capacity (million tons)		
Type of Benefit	10	20	30	10	20	30
	$ million					
Net economic benefit	76	107	124	69	77	81
Net financial benefits	55	60	63	48	60	60
Consumer benefits	1800	2690	3156	924	1272	1390
Producer benefits	−1781	−2641	−3095	−913	−1254	−1370

while producers make large gains from the added demand for food aid. However, in this case, the large distributional effect of storage operations can be regarded as merely compensating consumers for losses and producers for gains incurred by them as a consequence of food aid.

Viewed in another way, storage reduces the cost of food aid. Without storage, the annual expected amount of food aid is about 8 million tons, the expected price is $223 and the expected total cost is $2.3 billion.[7] A scheme involving a storage capacity of 20 million tons, operated under rule A, would reduce the expected quantity of food aid to approximately 6 million tons, the expected price to $197 and the expected cost to $1.4 billion. The cost saving is, however, largely offset by storage costs. The average net financial savings per annum amounts to about $60 million.

International Allocation of Costs and Benefits

The major cause for the current inaction on international reserve stock policy is the conflict of interest among nations. While the simulation model described does not directly estimate the international allocation of costs and benefits, the estimates of the gains to consumers and losses to producers provide some useful insights into the international conflict with regard to food grain buffer stocks. On the basis of these direct average gains and losses, nations which are net importers would tend to gain whereas countries which are net exporters would tend to lose from large reserve stocks. There are, of course, other reasons why nations have different views about the desirability of holding reserve stocks.

[7] As noted earlier, under the postulated policy the actual amount of food aid (or at least the portion of food aid which is relevant to reserve stock policy) will range from zero to 48 million tons, depending on the market price of wheat.

The gains or losses which accrue to each country can be estimated by summing the gains and losses of its consumers and producers. The effect of storage on an individual country's consumers or producers can be estimated by multiplying the country's respective shares in world consumption and production by the respective worldwide gains or losses of consumers and producers. These shares for groups of countries derived from trend values estimated by the Food and Agriculture Organization for 1970 are shown in table 8.

Assuming the consumer gains and producer losses associated with a 20-million ton storage capacity, operated under rule B, the country benefits (+) or losses (−), exclusive of the direct net cost of the storage operation, are presented in table 9.

The data in table 9 illustrate why it is so difficult to reach an international agreement. If demand is perceived to be relatively elastic, the distribution of gains and losses is not likely to be a stumbling block to an international understanding about sizable buffer stocks, since all countries prefer greater stability. Conflict might arise, however, over the sharing of the high cost of the storage operation itself. If demand is perceived to be inelastic,

Table 8. Shares in World Wheat Consumption and Production

	Shares (%) in World Wheat	
Groups of Countries	Consumption	Production
U.S., Canada, Australia	9.3	18.0
Europe and Japan	19.8	16.1
USSR	25.8	29.5
Centrally planned economics (excluding USSR)	18.9	16.1
Developing countries	26.2	20.3

Table 9. Expected Annual Gains and Losses by Groups of Countries from Reserve Stock with a 20-Million Ton Capacity Operated under Rule B

Types of Gains (+) and Losses (−)	Demand (1)	Demand (2)
	——$ million——	
Combined producer and consumer benefits by groups of countries		
U.S., Canada, Australia	−8	−115
Europe and Japan	10	60
USSR	3	−37
Centrally planned economies (excluding USSR)	9	48
Developing countries	14	93
Benefits from storage operations	−151	−91
Total benefits	−123	−42

Note: Demand (1) refers to the initially assumed demand function (elasticity = −0.15 when quantity = 332 million tons) and Demand (2) refers to assumed more inelastic demand when supplies are short (elasticity = −0.1 when quantity = 332 million tons).

the exporting countries might question the very desirability of holding buffer stocks, no matter who pays for them. In particular, farmer lobbies might present a strong case against stocks. While the expected annual direct net loss to the exporting countries is $115 million, their producers might be expected to suffer a loss of $248 million.

Estimates such as are reported in table 9 could provide a rational basis for negotiating cost-sharing schemes. It is beyond the scope of this paper to recommend any particular cost-sharing formulas, particularly since they need not be based exclusively on equalizing benefits. They could, for instance, be partially based on ability to pay, in the context of international aid programs to developing countries. In any case, more precise up-to-date information and better models which account for established trade barriers among countries are needed to replace the illustrative numbers presented in this paper.

Limitations of the Model

Several limitations of the present simulation model for projecting the consequences of storage operations for the world wheat economy have already been noted. These limitations and some additional qualifications are now briefly summarized. Suggestions on ways to improve any future analysis of this kind are also provided.

The storage rules are crude. More refined storage rules could increase the benefits (or reduce the costs) of operating storage schemes at any level. However, in my judgment, the order of magnitudes of stabilization and benefits and costs would not be much different with optimal storage rules and hence, the basic conclusions derived on the basis of crude storage rules would not change. In any case, it is questionable whether the implementation of any storage policy would exactly follow sophisticated storage rules.

The sum of the justifiable storage activity in different locations around the world would be larger than the amount of storage deemed sufficient on the basis of the simulation of storage requirements in a unified world market. Clearly, when surplus production in one location cannot be used for reducing production shortages in other locations, there is greater justification for stabilizing local production fluctuations through storage operations.

Annual production has been assumed to be a random independent variable. If production is characterized by systematic cycles, the stabilization effect of a given level of storage capacity will be less than if year-to-year production is not correlated, given the storage rules suggested in this study. However, if cycles could be predicted with any degree of reliability, storage rules could be designed which would lead to higher economic and financial benefits than are obtainable from storage rules appropriate to an environment of random, independent fluctuations for any desired fixed level of stabilization.

A static model, which abstracts from changes over time in demand and supply conditions, as used in the current study, is also relevant to projections in a dynamic world, but only under certain restrictive assumptions. One set of such assumptions is that the slope of the demand function does not change while shifting to the right, that expected production shifts at the same rate as the demand function, and that the absolute standard deviation of production remains the same. These are plausible but not sufficiently tested assumptions. Demand for food grain might become more inelastic as a consequence of higher per capita incomes over time; technological progress might make it possible to produce larger outputs without increasing costs and the relative standard deviation might decline as more production comes from irrigated land.

However, with different assumptions about trends, the results presented in this paper would need to be modified in a predictable

way. Constant elasticity over time implies that the slope of the demand function declines over time. Hence, the benefits from storage would decline for a fixed range of production and storage capacity. Alternatively, if the absolute standard deviation of production increases over time, storage capacity would have to be increased proportionally to attain a desired level of stabilization. If supply grows faster than demand, and, therefore, there is a downward trend in price, storage benefits would be reduced. Conversely, if demand grows faster than supply, and, therefore, price rises over time, benefits from storage would obviously be higher than calculated in the absence of a price trend.

The foregoing model has assumed that mean production would be the same with and without storage. This is clearly a strong assumption, given that stabilization decreases the expected price and its variability (as long as we postulate a concave demand function). While there is some evidence that production responds positively to a decline in price variability (Moscardi; Reutlinger 1963) and negatively to a decline in the expected price, it is difficult even to predict the direction of bias from failing to consider the expected supply response to storage without much more empirical evidence. Nevertheless, it would be worthwhile to construct models which explicitly account for the interaction of supply and demand.

Summary and Conclusions

The paper describes a simple simulation model for estimating the effects of operating a buffer stock scheme in the context of a unified world market. While the model is static, it can, under restrictive assumptions about trends in demand and supply and the coefficient of variation in production, be used to analyze the projected impact of alternative levels of storage activity. The aim of the storage rules is to stabilize available supplies. Since the expected supply is assumed to be the same with and without storage, the storage rules also implicitly imply a desired level of price stabilization.

Illustrative runs of the model yield some interesting conclusions. In the range of plausible demand elasticities, optimal levels of buffer stocks in terms of net benefits are likely to be too low to afford reasonably satisfactory protection against extreme shortfalls of grain and extremely high prices.

A storage scheme which operates with "insurance-oriented" storage rules under which grain is released only in years of extremely poor harvests can be very cost-effective for achieving a high level of protection against extreme shortfalls in grain supplies. With such storage rules, 20 million tons of storage capacity could reduce the probability of grain supplies being short by more than 5% of the mean from 13.6% to 4.6% and could reduce the probability of a shortfall in excess of 7.5% from 4% to 0.5%.

The annual negative net benefits, i.e., the annual insurance premium of an insurance-oriented program would be of the order of $50 million to $150 million, in the range of demand elasticities considered. In terms of the world's expected wheat production, this amounts to an insurance premium of the order of 20¢ to 50¢ per ton per annum.

The gains to consumers and the losses to producers can be sizable. Hence, it is very important to assess the distributional impact of storage schemes. The standard deviation of the expected gains or losses from the buffer stocks is very large, indicating the high risk of investments in such stocks arising from the progression of good and bad years in different thirty-year "samples" from a probability distribution of production.

If food aid between countries and within countries is a deliberate policy objective, the added demand during years of poor harvests has a significant effect on stock requirements and the benefits to be derived from operating buffer stocks.

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Welfare Implications of Stabilizing Consumption and Production

Abraham Subotnik and James P. Houck

Some economists are now urging the use of buffer stocks to help stabilize farm and food prices. Moreover, price stabilization has been shown to be socially beneficial from a theoretical point of view. Our purpose is to analyze the welfare implications of stabilized consumption and production and to compare them with the known implications of stabilized prices. It is shown that stabilized consumption is the least beneficial in its welfare implications. The relation between the gains from stabilization and the size of buffer stocks necessary to achieve stabilization also is analyzed. Finally, the presentation is extended to cover instability due to fluctuations in export demand.

Key words: buffer stocks, consumption stabilization, export stabilization, price stabilization, production stabilization, welfare gains.

Market stabilization has become an important issue in the controversy over establishing reserve stocks of grains. Among others, Cochrane has strongly urged the establishment of buffer stocks of agricultural products to help stabilize prices. However, Cochrane and others primarily concerned with public policy do not support their position from a theoretical point of view. Their objective seems to be the stabilization of prices as a goal in itself. Yet from a purely theoretical point of view, Massell has used conventional consumer and producer surplus analysis and some previous results obtained by Waugh (1944, 1961) and Oi to show that price stabilization with a buffer stock is socially beneficial compared to the free market. These particular results were obtained assuming that supply reacts instantaneously to a change in market prices. Similar results were obtained more recently by Turnovsky who analyzed the welfare implications of price stabilization under different assumptions concerning the behavior of supply.

Therefore, advocates of buffer stocks which stabilize prices could justify their positions theoretically. But if price stabilization can be justified in terms of social welfare, might it also be true that stabilizing other market variables will be even more beneficial? If maximizing social welfare is the policy objective, there is no a priori reason why stabilizing the quantities demanded or supplied should not be appropriate alternatives to price stabilization.

The main purpose of this paper is to analyze welfare implications of stabilized consumption and production and to compare them with welfare implications of stabilized prices which are already known. The focus of the analysis is on agricultural products where farmers cannot adjust instantaneously to changes in market prices. Therefore, producers' reaction to changes in expected prices and expectations are assumed to be "rational" within the context developed by Muth. This implies that, in the short run after planting decisions have been made, supply is completely inelastic. As a by-product of this analysis, the relation between the gains from stabilization and the size of the buffer stocks necessary to achieve the stabilizing goal also is shown. Finally, the analysis is extended to cover instability due to fluctuations in export demand.

Method of Analysis

In this discussion, the quantity supplied in any marketing period does not depend on current price but on expected price as visualized by producers at the time when their production decision was made. The basic model is

$$(1) \qquad \begin{aligned} D(P_t) &= \alpha_0 - \alpha_1 P_t + u_t \\ S(P^*_t) &= \beta_0 + \beta_1 P^*_t + v_t, \end{aligned}$$

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where D and S are the quantities demanded and supplied, P is the market price, and u and v are random elements affecting demand and supply. It is assumed that the error terms are independent with finite variances, σ_u^2 and σ_v^2; P^*_t is the expected price visualized by producers when production decisions for the marketing period t are made.

"Rational" price expectations, as Muth defines the term, means that producers decide on output according to the expected equilibrium price that would be obtained from the solution of the structural model. It follows that the expected price is

$$(2) \qquad P^* = \frac{\alpha_0 - \beta_0}{\alpha_1 + \beta_1}.$$

In the absence of stabilizing intervention, the competitive market solutions are

$$(3) \qquad P_e = \frac{\alpha_0 - \beta_0}{\alpha_1 + \beta_1} + \frac{u_t - v_t}{\alpha_1}$$

and

$$Q_e = \frac{\alpha_0\beta_1 + \alpha_1\beta_0}{\alpha_1 + \beta_1} + v_t.$$

The effects of any stabilizing scheme are measured in terms of consumers' and producers' surplus as compared to free market behavior.[1] The areas representing the consumers' and producers' surplus (gains or losses) are obtained as follows. Let P_e be the free market equilibrium price, P_s be the market price under any particular stabilization scheme, D_e and S_e be the free market equilibrium demand and supply respectively ($D_e = S_e = Q_e$), $D(K)$ and $S(K)$ be the demand and supply functions respectively for any of the stabilization schemes considered, and $K = P_s$, D_s, or S_s, indicating a price stabilization, consumption stabilization, or supply stabilization scheme, respectively. Then the consumer gains (or losses) due to any scheme are

$$(4) \quad G_c = \int_{P_s}^{P_e} D(P)dP = \int_{P_s}^{P_e} (\alpha_0 - \alpha_1 P)dP = 1/2(P_e - P_s)(D_e + D_s).$$

Similarly, the producers' gains (or losses) are

$$(5) \quad G_s = \int_{P_e}^{P_s} S(P)dP = \int_{P_e}^{P_s} (\beta_0 + \beta_1 P)dP = 1/2(P_s - P_e)(S_s + S_e).$$

The total gain or losses from any stabilizing scheme are

$$(6) \qquad G = G_c + G_s.$$

The levels at which the various market variables (price, quantity demanded, and quantity supplied) are stabilized correspond to their expected values under a free market system. Thus, stabilization is aimed at eliminating the free market randomness in the variable being stabilized.

Since welfare gains (or losses) measured in equations (4), (5), and (6) relate stabilization to randomly disturbed free market situations, these measured gains (or losses) are themselves random. Therefore, we compare the expected values of welfare gains (or losses) derived from various stabilization schemes.

The reason for dealing with a static model as in equation (1) is only for convenience. The addition of demand and supply shifters does not change the nature of most results obtained. Whenever a changing stabilized variable through time has an impact on the results, it is mentioned and analyzed.

The Analysis of Stabilizing Schemes

Price Stabilization

Price is assumed stabilized at

$$(7) \qquad P_s = \frac{\alpha_0 - \beta_0}{\alpha_1 + \beta_1}.$$

Hence, the market quantities demanded and supplied, and the change in government stocks are

$$D(P_s)_t = \frac{\alpha_0\beta_1 + \alpha_1\beta_0}{\alpha_1 + \beta_1} + u_t,$$

$$(8) \qquad S(P_s)_t = \frac{\alpha_0\beta_1 + \alpha_1\beta_0}{\alpha_1 + \beta_1} + v_t,$$

and

$$\Delta G_t(P_s) = v_t - u_t.$$

When these solutions are compared to the free market solution, the expected gains from price stabilization by consumers, producers, and in total are

$$(9) \qquad EG_c(P_s) = \frac{1}{2\alpha_1}(\sigma_u^2 - \sigma_v^2),$$

[1] The drawbacks of measuring welfare gain or loss by means of various areas associated with demand and supply functions are well known and have been dealt with extensively elsewhere. Those arguments will not be repeated here but should be kept in mind.

$$EG_s(P_s) = \frac{1}{\alpha_1}\sigma_v^2, \tag{10}$$

and

$$EG(P_s) = \frac{1}{2\alpha_1}(\sigma_u^2 + \sigma_v^2). \tag{11}$$

Producers are not affected by demand instability while consumers are affected by both sources of instability. Graphically, this is shown in figures 1 and 2.

When only demand is unstable and D_1 and D_2 are equally likely, then the free market solutions are at B and E in figure 1. With no price stabilization, the producers either lose the amount $ABCD$ or gain $CDEF$. Since on average they neither lose nor gain with a free market, it follows that by stabilizing price at P_s they also do not lose or gain. On the other hand, consumers will gain the area of $ABCG - CHFE$ from stabilized prices. The government will buy HD or sell DG.

When only supply is unstable and S_1 and S_2 are equally likely, then free market solutions are B and G in figure 2. Here the loss in consumers' surplus is the area of $FGCE - ABCE$ and the gain in producers' surplus is the area of $EFGH - ABED$. The government will either sell CD or buy CH. There is a simple relation between the total expected social gains and the variance of changes in government stocks, defined for a price stabilization scheme as $\sigma^2(P_s)$. Since $\sigma^2(P_s) = \sigma_u^2 + \sigma_v^2$, then

$$EG(P_s) = \frac{1}{2\alpha_1}\sigma^2(P_s). \tag{12}$$

Stabilization of Consumer Demand

Assume that the quantity demanded is stabilized at the expected free market equilibrium

$$D_s = \frac{\alpha_0\beta_1 + \alpha_1\beta_0}{\alpha_1 + \beta_1}. \tag{13}$$

The stabilization of consumer demand implies that the market price, the quantity supplied, and changes in government stocks are

$$P(D_s)_t = \frac{\alpha_0 - \beta_0}{\alpha_1 + \beta_1} + \frac{1}{\alpha_1}u_t,$$

$$S(D_s)_t = \frac{\alpha_0\beta_1 + \alpha_1\beta_0}{\alpha_1 + \beta_1} + v_t, \tag{14}$$

and

$$\Delta G(D_s)_t = v_t.$$

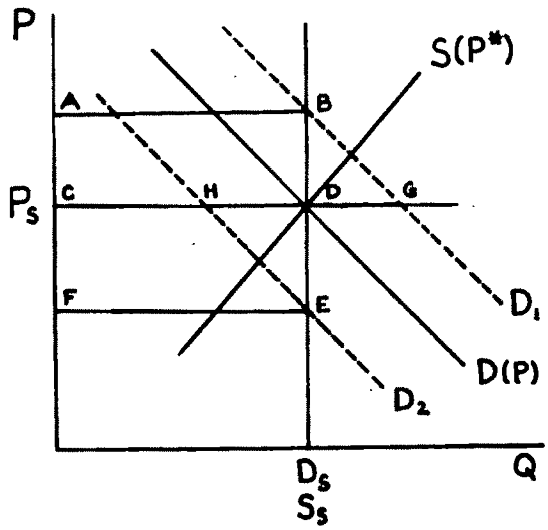

Figure 1. Welfare gains when demand is unstable

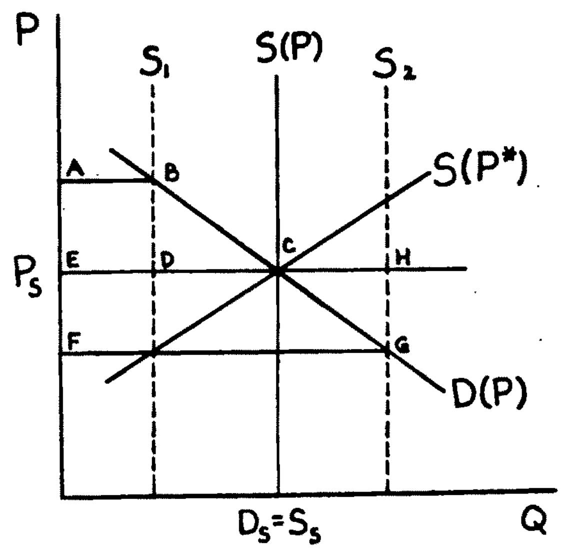

Figure 2. Welfare gains when supply is unstable

The government will buy or sell stocks to stabilize demand only if supply is unstable.

The stabilization of consumer demand produces these expected gains

$$EG_c(D_s) = \frac{-1}{2\alpha_1}\sigma_v^2, \tag{15}$$

$$EG_s(D_s) = \frac{1}{\alpha_1}\sigma_v^2, \tag{16}$$

and

$$EG(D_s) = \frac{1}{2\alpha_1}\sigma_v^2. \tag{17}$$

These gains are independent of demand instability.

Points B and E in figure 1 are free market equilibrium solutions for D_1 and D_2 respectively, when rational expectations apply. Such solutions do not require government intervention to satisfy the consumption target. Therefore, if consumption is stabilized and only demand is unstable, the free market solution will be the same as the stabilized solution. Since the solutions are the same, it follows that demand instability has no effect on consumer welfare. The graphical analysis of this scheme when supply is unstable is also shown in figure 2.

The variance of the change in government stocks is

$$(18) \qquad \sigma^2(D_s) = \sigma_v^2.$$

Hence,

$$(19) \qquad EG(D_s) = \frac{1}{2\alpha_1}\, \sigma^2(D_s).$$

Supply Stabilization

Next the supply target is assumed set at

$$(20) \qquad S_s = \frac{\alpha_0\beta_1 + \alpha_1\beta_0}{\alpha_1 + \beta_1}.$$

Once producers have decided their level of production, supply forthcoming will depend only on that production decision and on the random elements affecting supply. Thus, when supply is stabilized and expectations are rational, government must buy and sell stocks according to total quantity supplied. But the price at which purchases and sales are made depends on the supply target. We return to this point later.

When the supply target is set at S_s, then the quantities demanded and supplied, the market price, and the change in government stocks are

$$D(S_s)_t = \frac{\alpha_0\beta_1 + \alpha_1\beta_0}{\alpha_1 + \beta_1} + \frac{\alpha_1}{\beta_1} v_t + u_t,$$

$$(21) \qquad S(S_s)_t = \frac{\alpha_0\beta_1 + \alpha_1\beta_0}{\alpha_1 + \beta_1} + v_t,$$

$$P(S_s)_t = \frac{\alpha_0 - \beta_0}{\alpha_1 + \beta_1} - \frac{1}{\beta_1} v_t,$$

and

$$\Delta G(S_s)_t = \left(1 - \frac{\alpha_1}{\beta_1}\right) v_t - u_t.$$

The expected gains generated by this scheme are

$$(22) \qquad EG_c(S_s) = \frac{1}{2\alpha_1}\left(\sigma_u^2 + \frac{\alpha_1^2 - \beta_1^2}{\beta_1^2}\sigma_v^2\right),$$

$$(23) \qquad EG_s(S_s) = \frac{\beta_1 - \alpha_1}{\alpha_1\beta_1}\sigma_v^2,$$

and

$$(24) \qquad EG(S_s) = \frac{1}{2\alpha_1}\left[\sigma_u^2 + \left(1 - \frac{\alpha_1}{\beta_1}\right)^2 \sigma_v^2\right].$$

A better understanding of these analytical results may be gained by geometrically examining the effects of demand and supply instability on measures of social welfare. In figure 1, only the effects of unstable demand are shown. The supply target is satisfied at S_s. If demand shifts to D_1, the free market equilibrium is at B, since S_s is supplied under the rational expectations assumption. Only at G is the price paid by consumers the same as that expected by producers and used in production planning.

To achieve a solution at G, the government must sell stocks, driving the price down to P_e. Similarly, if D_2 occurred, the free market solution would be at E. The government then would buy stocks driving the price up to P_e. If D_1 and D_2 are equally likely, the expected gains by consumers will be increased by the area of $ABCG-CFEH$ which is positive. On the other hand, it can be shown that expected producers' gains are $ABCD-CDEF = 0$.

The effects of supply instability are more complex. Although the effect of supply instability is beneficial in terms of the total expected gains, its differential effect on consumers and producers depends on the relative size of α_1 and β_1. When $\alpha_1 > \beta_1$, supply instability is beneficial for expected consumer gains and detrimental for expected producer gains. The opposite holds for $\beta_1 > \alpha_1$.

Figure 3 illustrates the effects of supply instability when $\alpha_1 > \beta_1$. In this case, the supply curve $S(P^*)$ remains constant; the random effects change only the quantity supplied after the production decision is made. Assume that a shift to either S_1 or to S_2 is equally likely. When S_1 is supplied, government acquires BE of stocks driving the price up to E. This is because E is the price at which producers would produce S_s if they could adjust output given the random disturbance which actually occurred. Similarly if S_2 is supplied, govern-

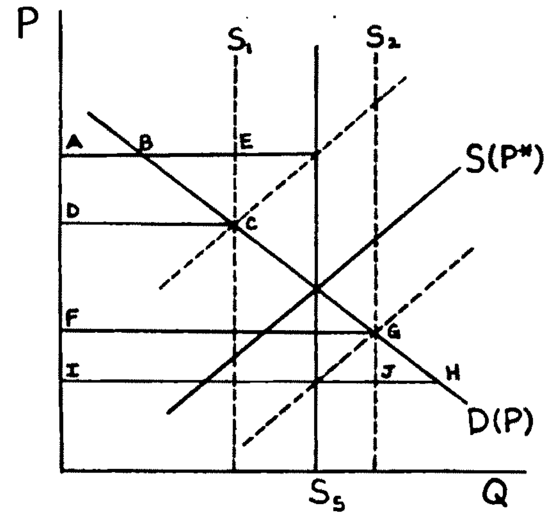

Figure 3. Welfare gains when supply is stabilized and $\alpha_1 > \beta_1$

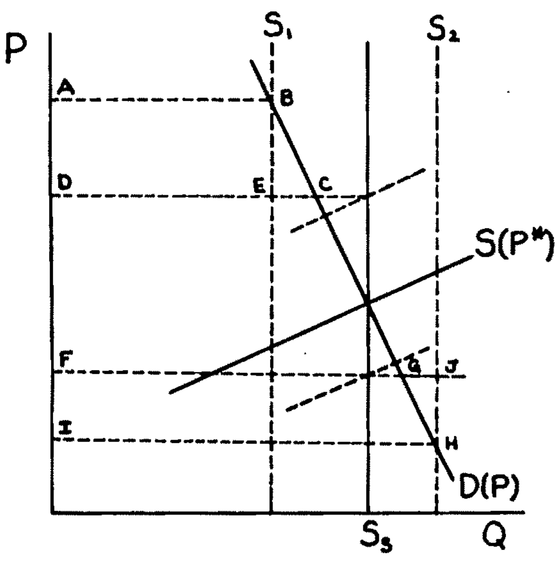

Figure 4. Welfare gains when supply is stabilized and $\beta_1 > \alpha_1$

ment will sell JH of stocks driving the price down to J. As a result, consumers' expected gains are $FGHI-ABCD$. Producers' expected losses are $FGIJ-AEDC$, and total expected gains are $BEC+GJH$.

Figure 4 illustrates the effects of supply instability when $\beta_1 > \alpha_1$. Assume S_1 and S_2 are equally likely. With S_1, the price which would induce producers to produce S_s (given their adjustment to the S_1 disturbance) is lower than the free market price. Similarly with S_2, the price which would induce production at S_s is higher than the free market equilibrium price.

It follows that if S_1 happens, government will sell EC stocks driving the price down to C. If S_2 happens, government will acquire GJ stocks driving the price up to G. As a result, consumers' expected losses are $HGFI-ABCD$, producers' expected gains are $FJHI-ABDE$, and total expected net gains are $BCE+GJH$.

Government intervention in supply stabilization may result in either increased or decreased price variability depending on the relative sizes of α_1 and β_1. Thus, either a deficit or a surplus in government expenditures can occur when considering a static model. In such a case, the expected deficit is $\frac{\sigma^2}{\beta_1^2}(\alpha_1 - \beta_1)$. When $\alpha_1 > \beta_1$, prices are destabilized, and a deficit will occur. When $\beta_1 > \alpha_1$, prices are more stable, and there will be a surplus. It is tempting to add or subtract this value from the expected social gains to arrive at a measure of net expected gains. In our view, this procedure is too restrictive for any real world application since equilibrium prices and quantities change through time because of systematic shifts in demand and supply.

While an expected budget loss at any given time depends on objective conditions at that time, the total budget situation, unlike the benefits and losses to society, depends on the previous behavior of equilibrium prices and quantities. Without all this previous data, it is difficult to integrate the budgetary aspects of these stabilization schemes. Therefore, this discussion is confined to the welfare implications of different stabilizing schemes without considering their budgetary implications.

The variance of changes in government stocks is

$$\sigma^2(S_s) = \left(1 - \frac{\alpha_1}{\beta_1}\right)^2 \sigma_v^2 + \sigma_u^2. \tag{25}$$

This variance is related to the expected social benefits as follows:

$$EG(S_s) = \frac{1}{2\alpha_1}\,\sigma^2(S_s). \tag{26}$$

Summary of Stabilization Schemes

Three stabilization schemes have been analyzed. The welfare implications of the different schemes do not depend on whether the system is static or whether equilibrium solutions change through time, if the demand and supply shifters are known with certainty. The

expected welfare gains at each point in time are independent of one another. On the other hand, the budgetary implications of the different schemes cannot be analyzed in the context of static models. They depend on the time path of the equilibrium prices and quantities.

Considering only the expected social gains and abstracting from budgetary considerations: if $\alpha_1 \geq 2\beta_1$, $EG(S_s) \geq EG(P_s) > EG(D_s)$, and if $\alpha_1 < 2\beta_1$, $EG(P_s) > EG(S_s) > EG(D_s)$. These results have a cost counterpart measured by the stocks needed by the government in order to carry out the different stabilizing schemes. Appealing to the Central Limit Theorem of statistics, we assume that the needed changes in government stocks are approximately normally distributed. This assumption becomes more realistic the larger the model and the more sources of instability are built into the system. It follows that in order to be effective in 95% of all possible cases, the government needs to hold about 1.96 times the standard deviation of stocks indicated under any particular scheme.

If a cost function for carrying stocks is known, then a price tag could be attached to each of the stabilizing schemes. But even if such cost functions are not known, the analysis at least provides a ranking of the different schemes according to their relative costs. These relative costs are directly related to the variance in government stocks associated with each scheme. It was shown that, for every scheme, the variance of the change in government stocks is proportional to expected social gains. Therefore, the storage costs involved can be ranked in the same order as the expected gains from the different stabilizing schemes. Therefore, if $\alpha_1 \geq 2\beta_1$, $\sigma^2(S_s) \geq \sigma^2(P_s) > \sigma^2(D_s)$, and if $\alpha_1 < 2\beta_1$, $\sigma^2(P_s) > \sigma^2(S_s) > \sigma^2(D_s)$. This shows that the more beneficial the scheme, the higher are the costs involved.

Stabilization Schemes When Foreign Demand is Unstable

The foregoing analysis may be extended to cover cases in which foreign trade adds an additional source of instability to the internal market. Hueth and Schmitz analyzed welfare implications of a price stabilization scheme when foreign markets are unstable and when internal supply reacts instantaneously to price change.

In this section, the welfare implications of the stabilizing schemes are analyzed when foreign markets are unstable and when internal supply reacts to a change in rational expectations. The demand for exports is assumed perfectly price inelastic but subject to random fluctuation. This facilitates the introduction of instability from foreign markets without losing generality from the results. Therefore, the level of exports will be reflected by

$$x_t = \bar{x}_t + \epsilon_t, \tag{27}$$

where $\bar{x}_t$ = expected levels of exports for time t known in t-1, and ϵ_t = random component of exports. It is assumed that ϵ_t is independently distributed of u_t and v_t and that its variance is finite at σ_ϵ^2. In addition, the country facing this fluctuating demand is assumed to be the only source of supply.

Following the earlier formulation of rational expectations, the model now becomes

$$\begin{aligned} D(P_t) &= \alpha_0 - \alpha_1 P_t + u_t, \\ S(P^*_t) &= \beta_0 + \beta_1 P^*_t + v_t, \end{aligned} \tag{28}$$

and

$$D(P_t) + x_t = S(P^*_t),$$

where because of rational expectations

$$P^*_t = \frac{\alpha_0 - \beta_0}{\alpha_1 + \beta_1} + \frac{1}{\alpha_1 + \beta_1} (\bar{x}_t). \tag{29}$$

It follows that the free market solutions are

$$D_E = \frac{\alpha_0\beta_1 + \alpha_1\beta_0}{\alpha_1 + \beta_1} - \frac{\alpha_1}{\alpha_1 + \beta_1} (\bar{x}_t) - \epsilon_t + v_t, \tag{30}$$

$$P_E = \frac{\alpha_0 - \beta_0}{\alpha_1 + \beta_1} + \frac{1}{\alpha_1 + \beta_1} (\bar{x}_t) + \frac{u_t - v_t + \epsilon_t}{\alpha_1}, \tag{31}$$

and

$$S_E = \frac{\alpha_0\beta_1 + \alpha_1\beta_0}{\alpha_1 + \beta_1} + \frac{\beta_1}{\alpha_1 + \beta_1} (\bar{x}_t) + v_t. \tag{32}$$

By assumption, all sources of instability are independent. Since demand and supply instability have been analyzed and since these effects are additive, we now focus on export instability separately.

It can be shown that, for all schemes analyzed in this paper (stabilized prices, domestic consumption, and production), export insta-

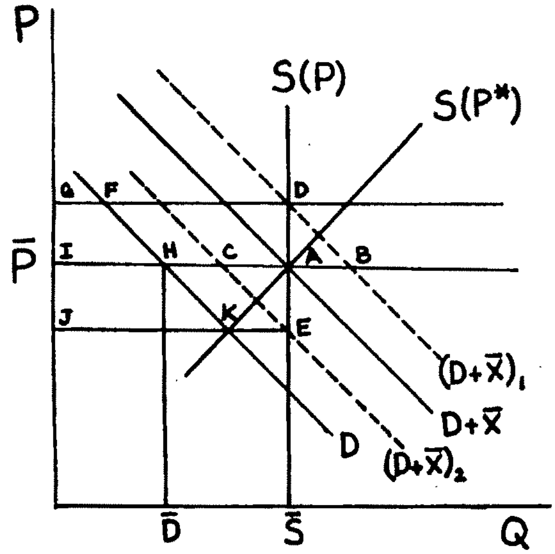

Figure 5. Welfare gains when exports are unstable

bility has the same effect. Consider figure 5 where $ED_E = \bar{D}$, $ES_E = \bar{S}$, $EP_E = \bar{P}$. The barred variables are the expected values of the endogenous variables. These expected values, in turn, are the levels at which consumption, production, and price, respectively, are stabilized.

Let $(D + \bar{x})_1$ be as likely as $(D + \bar{x})_2$. If price is to be stabilized, it will be set at $\bar{P}$. It follows that if $(D + \bar{x})_1$ occurs, government will sell the AB stocks driving the price down to $\bar{P}$. At the stabilized price, domestic consumption will be $\bar{D}$ and production will be $\bar{S}$. Similarly, if total demand shifts to $(D + \bar{x})_2$, government will buy AC stocks, and prices will settle at $\bar{P}$. At $\bar{P}$, domestic consumption and production remain at $\bar{D}$ and $\bar{S}$, respectively.

If production is stabilized, it will be at $\bar{S}$. If a random shift to $(D + \bar{x})_1$ happens, the government sells AB stocks. Domestic demand settles at $\bar{D}$ and price at $\bar{P}$. If the random shift is to $(D + \bar{x})_2$, the price will be raised to $\bar{P}$ as the government acquires AC stocks. Again, domestic demand settles at $\bar{D}$.

If domestic consumption is stabilized, it will be at $\bar{D}$. By the same reasoning outlined above, domestic consumption is stabilized at $\bar{D}$ only if the price is $\bar{P}$ and supply is $\bar{S}$. This is achieved by the government's either selling AB stocks or buying AC stocks. Consequently, when exports are unstable, all stabilization schemes analyzed exhibit the same effects on expected gains of producers and domestic consumers.

In terms of figure 5, the expected gains in consumer welfare are negative and measured by the area $HIJK - FGIH$. On the other hand, since supply becomes completely inelastic at its expected equilibrium level, the expected producer gains are zero because the gains ($IAJE$) equal the losses ($GDIA$). Analytically,

$$EG_C = EG = -\frac{1}{2\alpha_1}\sigma_\epsilon^2.$$

In this case, stabilization policies at home when exports are unstable become a burden only on domestic consumers. This is because, by stabilizing the internal market, the gains derived from avoiding higher prices are smaller than the losses derived from being unable to buy at lower prices. Hence, if exports are the only source of instability in the system, no stabilizing scheme will improve social welfare.

However, if we include welfare effects of stabilization on the importers, these results change. Returning to figure 5, it can be seen that in this broader case, expected consumer gains (domestic and foreign) become positive and are measured by $GDIB - ICEJ$. Expected producer gains do not change. Analytically, the total expected gains (domestic and foreign) from stabilization at home are

$$EG^T = \frac{1}{2\alpha_1}\sigma_\epsilon^2. \tag{33}$$

The world as a whole benefits from any stabilization scheme in a single exporting nation when export demand is unstable. The difference between world expected gains and domestic expected gains is the expected benefit which the importing country derives from stabilization by the exporter

$$EG^T - EG = \frac{1}{\alpha_1}\sigma_\epsilon^2. \tag{34}$$

This expected benefit is equal to the expected savings in import outlays due to stabilization by the exporter. This can be shown as follows:

$$M = (\bar{P} + \eta)(\bar{x} + \epsilon), \tag{35}$$

where M = import outlay and $\eta = \frac{\epsilon}{\alpha_1}$. When the internal market is not stabilized, the expected outlay becomes

$$EM = \overline{PX} + \frac{\sigma_\epsilon^2}{\alpha_1}. \tag{36}$$

On the other hand, when the internal market is stabilized, the expected outlay becomes

$$EM^* = \overline{PX}. \tag{37}$$

Therefore,

$$EM - EM^* = \frac{\sigma_\epsilon^2}{\alpha_1} \tag{38}$$

is the additional expected import outlay when the domestic market is not stabilized. It represents expected savings to the importing country due to market stabilization at home by the exporter.

These results indicate some trade policy issues which become relevant when stabilization schemes are considered. For example, the export nation might wish to eliminate export instability by contracting in advance with foreign countries. This, in turn, might require the administration of a new buffer stock or inventory management scheme in the importing countries. Alternatively, if importing countries are not willing to contract, the exporter might stipulate export quotas in advance. If no quotas or advanced contracting are possible, the domestic market might be stabilized and importing countries might be levied an amount equal to $\sigma_\epsilon^2/\alpha_1$. This result would benefit the exporter and lead to free market behavior in world markets.

Since export instability affects the expected welfare gains derived from each of the stabilization schemes identically, its occurrence does not alter the relative ranking of the schemes in terms of welfare gains or storage costs.

Summary

This paper presents analyses of welfare implications of the deliberate stabilization of either consumption or production and then compares those results with the welfare implications of stabilized prices which are already known. Supply is assumed to behave according to the rational expectation model. Unstable export demand also is added to the plausible, but abstract, theoretical models investigated.

The ordinal welfare ranking of these three schemes depends upon the relative size of the demand and supply price response coefficients.[2] In all cases, demand stabilization is the least beneficial in its welfare implications. To the extent that the operating costs of various stabilization schemes are directly related to the associated variance in government stocks, the ordinal ranking from high to low on welfare grounds is the same as the ordinal ranking of high to low on cost grounds.

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[2] The rational expectation model does not result in exactly the same ranking of stabilization schemes as one in which producers react instantaneously to a change in market prices. In the latter case, the following holds. If $\alpha_1 > \beta_1$, $EG(S_s) > EG(P_s) > EG(D_s)$ and $\sigma^2(S_s) > \sigma^2(P_s) > \sigma^2(D_s)$. If $\beta_1 > \alpha_1$, $EG(D_s) > EG(P_s) > EG(S_s)$ and $\sigma^2(D_s) > \sigma^2(P_s) > \sigma^2(S_s)$.

Prices and Demands for Input Characteristics

George W. Ladd and Marvin B. Martin

Price of an input equals the sum of the money values of the input's characteristics to the purchaser; money value of each of an input's characteristics equals the input's yield of the characteristic multiplied by the money value of one unit of the characteristic. Demand for an input is affected by the input's characteristics. The themes are derived from a neoclassical firm model, in which the arguments of the firm's production function are quantities of input characteristics used, and from duals of linear programming blending problems. These themes are used to evaluate corn grades.

Key words: grades, hedonic prices, product characteristics.

For some analyses, it is adequate to assume product homogeneity, but the essence of some problems involves product heterogeneity. Among these latter are problems involving product differentiation, quality, and grades and standards.

We suggest taking a product characteristics approach to the study of product heterogeneity. This approach views a product as a collection of characteristics. Then product heterogeneity arises in various ways. Two products can possess different amounts of the same characteristics or one product can contain a characteristic that the other does not. Two products may contain two completely different sets of characteristics.

In this paper we apply the product characteristics approach to production inputs. In another paper, Ladd and Suvannunt apply the approach to consumer goods. Taking product characteristics as the basic element permits us to do a number of things that we cannot do when we take product as the basic element of analysis. The potentialities of the product characteristics approach to inputs are summarized in the two themes of this paper.

The first theme is that the price of a purchased input equals the sum of the money values of the input's characteristics to the purchaser. The money value of each of the input's characteristics equals the input's marginal yield of the characteristic multiplied by the marginal money value of one unit of the characteristic. The second theme is that the demand for an input is affected by the input's characteristics.

The first section of this paper uses a variant of neoclassical firm theory to derive the two hypotheses stated in the themes and summarizes available statistical studies that bear on these two hypotheses. The next section uses linear programming to derive the hypothesis stated in the first theme and presents results of a study in which linear programming was used to measure the marginal money values of characteristics referred to in the first theme. The subsequent section uses the linear programming results in an evaluation of the present corn-grading system. The next section applies the second theme to the question: What quality of product should a firm produce for maximum profit?

Neoclassical Input Characteristics Model (ICM)

Differences in yields of input characteristics affect producers. A soybean crusher is concerned with the yield of oil and meal per bushel of beans. The amount of nitrogen in a ton of fertilizer makes a difference to a corn producer. This section of the paper presents a variation of neoclassical firm theory that focuses on the role of input characteristics in the production process. This section and the next two are partially a condensation and partially an extension of Martin's thesis.

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Theoretical Model

In this model of a multiproduct firm, each production function is independent of the production functions for other products. The assumption of independence of production functions plays the same role here that the assumption of independence of processes plays in linear programming.

Productive inputs are useful because they contain useful characteristics. The total contribution of an input to production depends upon the amounts of the various characteristics it provides, and total production depends upon the total amounts of all characteristics provided by all inputs. Let v_{ih} = the quantity of the ith input used in the production of the hth product, r_i = the price paid for the ith input, p_h = the price received for product h, q_h = the quantity of the hth output produced, x_{jih} = the amount of characteristic j provided by one unit of input i that enters into production of product h, and $x_{j\cdot h}$ = the total quantity of characteristic j that enters into production of product h. For example, q_h, x_{jih} and $x_{j\cdot h}$ might be amount of choice beef produced, the amount of protein in a bushel of No. 2 yellow corn that is used in production of choice beef, and total amount of protein used in production of choice beef. The values of x_{jih} are assumed to be parameters whose values are beyond the control of the user of the inputs. Write the production function for product h as

$$(1) \qquad q_h = F_h(x_{1\cdot h}, x_{2\cdot h}, \ldots, x_{m\cdot h}).$$

Equation (1) states that the output of the hth product depends upon the amounts of various input characteristics used in its production. The amount of choice beef produced, for example, depends upon the amounts of protein, carbohydrates, calories, vitamin A, etc., fed to the beef. Because total quantity of each characteristic can be expressed as a function of quantities of inputs used and of characteristic input-output coefficients, $x_{j\cdot h}$ can be written as

$$x_{j\cdot h} = X_{jh}(v_{1h}, v_{2h}, \ldots, v_{nh}, x_{j1h}, x_{j2h}, \ldots, x_{jnh}).$$

It follows that the production function can be written as

$$q_h = G_h(v_{1h}, v_{2h}, \ldots, v_{nh}, x_{11h}, x_{12h}, \ldots, x_{mnh}).$$

The firm's profit function can be written as

$$(2) \qquad \pi = \sum_{h=1}^{H} p_h F_h(x_{1\cdot h}, x_{2\cdot h}, \ldots, x_{m\cdot h}) - \sum_{h=1}^{H} \sum_{i=1}^{n} r_i v_{ih}.$$

The firm is assumed to maximize profit.

Because F_h is a function of the $x_{j\cdot h}$ and the $x_{j\cdot h}$ are functions of v_{ih}, to differentiate equation (2) with respect to v_{ih}, we use a rule for differentiating a compound function (a function of functions). According to this rule,

$$\partial F_h/\partial v_{ih} = \sum_j (\partial F_h/\partial x_{j\cdot h})(\partial x_{j\cdot h}/\partial v_{ih}).$$

Using this expression in differentiating equation (2) yields

$$(3) \qquad \partial\pi/\partial v_{ih} = p_h \sum_{j=1}^{m} (\partial F_h/\partial x_{j\cdot h})(\partial x_{j\cdot h}/\partial v_{ih}) - r_i = 0.$$

Solving for r_i,

$$(4) \qquad r_i = p_h \sum_j (\partial F_h/\partial x_{j\cdot h})(\partial x_{j\cdot h}/\partial v_{ih});$$

$\partial x_{j\cdot h}/\partial v_{ih}$ is the marginal yield of characteristic j to production of the hth product from the ith input; $\partial F_h/\partial x_{j\cdot h}$ is the marginal physical product from one unit of characteristic j used in production of the hth product; and $p_h \partial F_h/\partial x_{j\cdot h}$ is the value of the marginal product of the jth characteristic used in production of output h. It can be interpreted as the marginal implicit (or imputed) price paid for the jth product characteristic used in product h. Let $p_h \partial F_h/\partial x_{j\cdot h} = T_{jh}$. Then equation (4) can be written

$$(5) \qquad r_i = \sum_j T_{jh}(\partial x_{j\cdot h}/\partial v_{ih});$$

$T_{jh}\partial x_{j\cdot h}/\partial v_{ih}$ is the value of the marginal yield of the jth characteristic by the ith input in production of output h. Equation (5) states that for each input used in producing output h, the price paid equals the sum of the values of the marginal yields of the input's characteristics to the product. This is the hypothesis stated previously in the first theme.

To obtain the hypothesis stated in the second theme, note that the first-order conditions, equation (3), are a system of nH equations in the nH unknowns v_{ih}. If the second-order conditions for a maximum are satisfied, then the system has a solution, each element of which can be expressed as

$$(6) \qquad v_{ih^*} = V_{ih}(p_1, p_2, \ldots, p_H, r_1, r_2, \ldots, r_n, x_{111}, x_{211}, \ldots, x_{21H}, \ldots, x_{mnH}).$$

In general, it cannot be shown that $\partial v_{th^*}/\partial x_{uvw} = 0$. Thus, we have the second theme.

To look at this in more detail, consider a simple case of a single product firm. Then $h = 1$ and we will suppress the subscript h. From equation (3) we then have n equations of the form

$$(7) \quad \partial\pi/\partial v_i = p\Sigma\partial F/\partial v_i - r_i = 0; \quad i = 1, 2, \ldots, n.$$

Now suppose that the producer of the wth input changes the composition of his product slightly by varying x_{uw} by the amount dx_{uw}. What effect will this change have on the firm's level of use of various inputs? The answer to this question can be expressed in easily understood terms if first the effect of a change in the price of one input on input use is determined. Suppose the price of input g varies. To determine the effect, differentiate the n expressions in equation (7) with respect to r_g and solve for $\partial v_t/\partial r_g$. Define D = symmetric $n \times n$ determinant whose element in row i and column t is $\partial^2 F/\partial v_i \partial v_t$, and D_{it} = cofactor of element in row i and column t of D. The solution for $\partial v_t/\partial r_g$ can be written as $\partial v_t/\partial r_g = D_{gt}/pD$.

The effects of a variation in x_{uw} are found by differentiating equation (7) with respect to x_{uw} and solving for $\partial v_t/\partial x_{uw}$. Let $f_g = \partial F/\partial v_g$ = marginal physical productivity of gth input. Then

$$(8) \quad \partial v_t/\partial x_{uw} = -\sum_g(\partial f_g/\partial x_{uw})(D_{gt}/pD) = -\sum_g(\partial f_g/\partial x_{uw})(\partial v_t/\partial r_g).$$

In the simple case where changing x_{uw} affects only f_u,

$$(9) \quad \partial v_t/\partial x_{uw} = -(\partial f_u/\partial x_{uw})(\partial v_t/\partial r_u).$$

Thus, the effect of a change in the composition of the wth input on demand for the tth input depends upon the effect of the change upon marginal physical productivities of all inputs, and the effect of changes in input prices on demand for the tth input.

We cannot demonstrate on a priori grounds that equation (8) or (9) equals zero. Therefore, equations (6) and (8) provide the hypothesis stated in the second theme.

Empirical Tests

Equation (5) provides the hypothesis: for each input purchased by the firm, the price paid equals the sum of the products of marginal yields of characteristics and marginal implicit prices of characteristics. Testing of this hypothesis is simplified by assuming $\partial x_{j\cdot h}/\partial v_{ih} = x_{jih}$ = constant. This assumption is consistent with the present state of knowledge. Data on product yields of characteristics, e.g., protein per bushel of No. 2 yellow corn, thiamine per pound of round steak, British thermal unit per cubic foot of natural gas, etc., treat yields of characteristics as constants. The data are consistent with an even stronger assumption, namely $x_{jih} = x_{jik}$ for all h and k and all i and j. This states that yield of each characteristic by an input is not affected by the use made of the input: the yield of protein from a bushel of No. 2 yellow corn is the same whether the corn is used to feed hogs or to feed dairy cattle. Assuming $\partial x_{j\cdot h}/\partial v_{ih} = x_{jih}$ = constant and T_{jh} = constant, equation (5) can be written

$$(10) \qquad r_i = \sum_j T_{jh} x_{jih}.$$

Regressing input prices (r_i) upon input characteristics (as measured by x_{jih}) provides a test of the null hypothesis that r_i is not linearly related to the x_{jih}. If the F test for significance of the regression coefficients leads to rejection of the null hypothesis, the data are consistent with the first theme.

If the T_{jh} are not believed constant, one might use

$$(11) \quad r_i = \sum_j x_{jih}\beta_j + \sum_j x^2{}_{jih}\beta_{jj} = \sum_j x_{jih}(\beta_j + x_{jih}\beta_{jj})$$

and determine marginal implicit prices from the terms in parentheses.

Studies by Waugh (1928, 1929), Fettig, Hyslop, and Wachtel and Betsey provide empirical tests of equation (5). All are consistent with the first theme. Waugh found that a substantial portion of the variance in wholesale prices of asparagus, tomatoes, and cucumbers could be explained by characteristics of the vegetables. Waugh collected data on wholesale prices and characteristics of individual lots of asparagus, tomatoes, and cucumbers. He regressed the ratio of the price of each lot to the average price of the product on measures of product characteristics and converted the regression coefficients into prices of product characteristics. For example, from his analysis of prices of asparagus, he concluded that each additional inch of green color per stalk added 38.45¢ to the price of one dozen standard bunches, that each additional stalk per bunch reduced price by 4.6¢,

and that each additional percent variation in size of stalk decreased price by 0.76¢ per dozen standard bunches. For asparagus and tomatoes he used a linear equation, like equation (10). For cucumbers he found a nonlinear relation like equation (11) to be superior to a linear relation.

Fettig found that a large proportion of variance in prices of farm tractors could be explained by horsepower and type of engine. His equation for 1962 prices, for example, was

$$p_i = 288.01 + 53.76H_i + 583.51D_i,\ R^2 = 0.876,$$

where p_i was FOB factory price of ith model of tractor, H_i was horsepower, and $D_i = 1$ if ith model had a diesel engine, and $D_i = 0$ otherwise. Hyslop analyzed prices of hard red spring wheat. He found that a large proportion of the variance in prices could be explained by a linear combination of percentage dockage, protein content, test weight, percentage damaged kernels, percentage of foreign material, percentage of shrunken and broken kernels, area of origin, destination, and transport mode.

Wachtel and Betsey found that an employee's annual wage earnings was linearly related to the employee's years of experience in his present job, race, age, sex, years of education, and marital status. These are the only studies to our knowledge that test the hypothesis of equation (5) and the first theme. Their results are all consistent with the first theme.

Many other studies have found that earnings are related to employee characteristics (see, e.g., Mincer; Johnson and Stafford; Malkiel and Malkiel; Griliches and Mason). But their results cast no light on the hypothesis in equation (5) that price is equal to the sum of the products of marginal yields of characteristics and marginal implicit prices. Their studies used equations of the form $\log r_i = \Sigma T_{jh} x_{jih}$.

We have not found any studies that test the hypothesis of the second theme.

Linear Programming Input Characteristics Model

Theoretical Background

The preceding argument justifies multiple regression as one method for assigning monetary values to characteristics of inputs. That argument applies to any production activity. Application of duality relationships to linear programming blending problems also provides a derivation of the first theme and a method of assigning monetary values to characteristics of inputs used in blending problems, e.g., blending pure metals to produce an alloy, feed mixing. This section discusses appropriate duality relationships. Two different blending problems are treated.

The first is the problem of blending ingredients purchased at fixed prices in order to minimize the ingredient cost of one unit of output. The problem can be stated as

$$\text{(12)} \qquad \min \sum_{j=1}^{n} p_j x_j$$

subject to

$$\text{(13)} \quad \sum_j a_{ij} x_j \geq a_{i0}:\ i = 1, 2, \ldots, m_0,$$

$$\text{(14)} \quad \sum_j a_{ij} x_j = a_{i0}:\ i = m_0 + 1, m_0 + 2, \ldots, m,$$

$$\text{(15)} \quad x_j \geq 0:\ j = 1, 2, \ldots, n_0,$$

and

$$\text{(16)} \quad x_j \text{ unrestricted: } j = n_0 + 1, n_0 + 2, \ldots, n.$$

Here p_j is the price of the jth ingredient; x_j is the quantity of the jth ingredient used per unit of output; a_{ij} is the quantity of the ith nutrient (or other characteristic) in one unit of the jth purchased input; and a_{i0} is the amount of the ith nutrient (or other characteristic) required in one unit of output. The dual to this problem is

$$\text{(17)} \qquad \max \sum_{i=1}^{m} a_{i0} y_i,$$

subject to

$$\text{(18)} \quad \sum_i a_{ij} y_i \leq p_j:\ j = 1, 2, \ldots, n_0,$$

$$\text{(19)} \quad \sum_i a_{ij} y_i = p_j:\ j = n_0 + 1, n_0 + 2, \ldots, n,$$

$$\text{(20)} \quad y_i \geq 0:\ i = 1, 2, \ldots, m_0,$$

and

$$\text{(21)} \quad y_i \text{ unrestricted: } i = m_0 + 1, m_0 + 2, \ldots, m.$$

Equations (13) and (20) state that the first m_0 primal constraints are "greater than or equal to" constraints and the first m_0 dual variables are nonnegative. Equations (14) and (21) state

that the remaining primal constraints are equalities and the remaining dual variables are unrestricted in sign. Equations (15) and (18) state that the first n_0 primal variables are nonnegative and the first n_0 dual constraints are "less than or equal to" constraints. Equations (16) and (19) state that the remaining primal variables are unrestricted and the remaining dual constraints are equalities.[1]

From duality theory, the minimum value of $\Sigma p_j x_j$ equals the maximum value of $\Sigma a_{i0} y_i$; write this as min $\Sigma p_j x_j$ = max $\Sigma a_{i0} y_i$. Now suppose that a_{i0} is changed by the amount Δa_{i0}. Then

$$\Delta\min \Sigma p_j x_j / \Delta a_{i0} = \Delta\max \Sigma a_{i0} y_i / \Delta a_{i0} = y_i,$$

and y_i is interpreted as the shadow price of the ith characteristic. It measures both the effect on minimum total ingredient cost per unit of output of varying a_{i0} and also the effect on maximum monetary value of nutritional (or other characteristic) requirements of varying a_{i0}. Then each constraint in equation (19) states: the total money value of all characteristics in one unit of input j (for $j = n_0 + 1, n_0 + 2, \ldots, n$) equals the price of ingredient j. (This is an exact counterpart to equation (5).) Letting x_{j*} and y_{i*} denote optimal values of primal and dual variables, a duality theorem tells us that if $x_{j*} > 0$ in the optimal solution to equation (12), then $\Sigma a_{ij} y_{i*} = p_j$. This expression is also an exact counterpart to equation (5). Hence, linear programming provides a derivation of the first theme.

The second blending problem concerns a firm that has a number of bins of corn, and the characteristics of each bin are known. Hence, the firm knows how many pounds of corn, of damaged kernels, etc., it has in each bin and in total. Let r_i = total stock of the ith characteristic (e.g., number of pounds of corn or of damaged kernels), x_j = quantity of jth output blended and sold, c_j = net revenue (selling price minus per unit blending cost) of jth output, and a_{ij} = amount of ith characteristic required per unit of jth output. This firm's profit-maximizing blending problem is

$$(22) \qquad \max \sum_j c_j x_j,$$

subject to

$$\sum_j a_{ij} x_j \leq r_i: i = 1, 2, \ldots, m_0,$$
$$\sum_j a_{ij} x_j \geq r_i: i = m_0 + 1, m_0 + 2, \ldots, m_1,$$
$$\sum_j a_{ij} x_j = r_i: i = m_1 + 1, m_1 + 2, \ldots, m,$$
$$x_j \geq 0: j = 1, 2, \ldots, n_0,$$

and

$$x_j \text{ unrestricted}: j = n_0 + 1, n_0 + 2, \ldots, n.$$

The dual to this problem is

$$(23) \qquad \min \sum_i r_i y_i$$

subject to

$$\sum_i a_{ij} y_i \geq c_j: j = 1, 2, \ldots, n_0,$$
$$\sum_i a_{ij} y_i = c_j: j = n_0 + 1, n_0 + 2, \ldots, n,$$
$$y_i \geq 0: i = 1, 2, \ldots, m_0,$$
$$y_i \leq 0: i = m_0 + 1, m_0 + 2, \ldots, m_1,$$

and

$$y_i \text{ unrestricted}: i = m_1 + 1, m_1 + 2, \ldots, m;$$

$\Delta\max \Sigma c_j x_j / \Delta r_i = \Delta\min \Sigma r_i y_i / \Delta r_i = y_i$; y_i is the shadow price of the ith characteristic. It is the maximum amount the firm can afford to pay for one more unit of the ith characteristic; it is also the reduction in net revenue resulting from reducing the firm's stock of the ith characteristic by one unit.

Assume the firm considers buying one bushel of corn at price p. Let Δr_i be the amount of the ith characteristic in the bushel of corn. Then the resulting change in the firm's net revenue is

$$(24) \quad \Delta\max \Sigma c_j x_j = \sum_i (\Delta\max \Sigma c_j x_j / \Delta r_i) \Delta r_i = \sum_i y_i \Delta r_i.$$

The firm can afford to buy and use the bushel of corn if

$$(25) \qquad \Sigma y_i \Delta r_i \geq p.$$

Equation (25) is an inequality variant of the first theme; $\Sigma y_i \Delta r_i$ is the maximum price the firm can afford to pay for the bushel of corn having the specified characteristics.

Some Empirical Results for Corn

The linear program, equation (22), was used to determine the optimum use of four carloads of corn actually shipped from a central Iowa elevator in the fall of 1971. The values of r_i

[1] The authors are aware that few blending problems contain unrestricted variables. Suppose that the first restriction is $\sum_j a_{1j} x_j \leq a_{10}$. Multiplying both sides of this constraint by -1 reverses the sense of the inequality and the resulting restriction has the same form as equation (13). Then equation (20) becomes $y_1 \leq 0$; $y_i \geq$ for $i = 2, \ldots, m_0$.

Table 1. Linear Programming Corn-Blending Problem 11

Characteristic i	Values of a_{ij}: $j = 1$[a]	$j = 2$	$j = 3$	$j = 4$	$j = 5$	Form of Constraint	r_i
$i = 1$: moisture	0.140	0.155	0.175	0.200	0.230	≥	1,851 bu.
$i = 2$: test weight	56.000	54.000	52.000	49.000	46.000	≤	675,024 lb.
$i = 3$: BCFM	0.020	0.030	0.040	0.050	0.070	≥	560 bu.
$i = 4$: damaged kernels	0.030	0.050	0.070	0.100	0.150	≥	168 bu.
$i = 5$: weight	56.000	56.000	56.000	56.000	56.000	=	672,000 lb.
c_j: \$/bu.	1.00	1.00	0.91	0.79	0.63		

[a] Value of j identifies grade of corn produced by blending and sold.

measured the amounts of moisture, test weight, broken corn and foreign material (BCFM), damaged kernels, and actual weight of the four carloads of corn. Five products could be obtained by blending this corn: United States No. 1, 2, 3, 4, and 5 corn. The amount of ith characteristic required per bushel of the jth grade of corn = a_{ij}. For moisture, BCFM and damaged kernels, a_{ij}, equals the official U.S. specification for the maximum amount of the ith characteristic allowed per bushel of the jth grade of corn. For test weight, a_{ij} equals the minimum official test weight per bushel of jth grade of corn. Eleven problems were obtained by varying BCFM in fifty-six bushel increments above and below its actual value. Problem 11 is shown in table 1.

The interest here is not in the amounts of various products to blend and sell, as it usually is in blending problems. In accordance with the first theme, the interest is in the implicit (shadow) prices of the various characteristics. Table 2 summarizes the values of the shadow prices from the optimal solutions to the 11 blending problems; these shadow prices are the y_i in problem (23).

In the solution to problem 11, for example, the shadow price for weight is 2.29¢ per pound. A firm whose stocks of corn were as described in the last column of table 1 could have increased its net revenue (sales revenue minus blending costs) by 2.29¢ if it had owned one more pound of corn. This means that the firm could have afforded to pay 2.29¢ for a pound of corn; it also means that the firm's net revenue would have been 2.29¢ less if it had owned one less pound of corn. Variations in the firm's stocks of moisture, test weight, or damaged kernels would not have affected the firm's net revenue.

Table 2 shows that weight had a positive shadow price in each solution. BCFM had a zero shadow price in each of the first five

Table 2. Shadow Prices for Linear Programming Corn-Blending Problems 1 through 11

Characteristic	Imputed (shadow) Prices[a]
Solutions 1 through 5: BCFM = 0; 56; 112; 168; 224 bu.	
Moisture	0
Test weight	0
BCFM	0
Damage	0
Weight	1.78
Solutions 6 and 7: BCFM = 280; 336 bu.	
Moisture	0
Test weight	0
BCFM	−900
Damage	0
Weight	2.26
Solutions 8 and 9: BCFM = 392; 448 bu.	
Moisture	0
Test weight	0
BCFM	−933.30
Damage	0
Weight	2.26
Solutions 10 and 11: BCFM = 504; 560 bu.	
Moisture	0
Test weight	0
BCFM	−933.30
Damage	0
Weight	2.29

[a] Cents per bushel for moisture, BCFM and damaged kernels; cents per pound for test weight and weight.

solutions and had a negative shadow price in each of the last six solutions. Shadow prices for all other characteristics were zero in all solutions.

These four carloads of corn happened to grade fairly high. Another solution—No. 12—was obtained in which the r_i for test weight was reduced by 5.5% and the r_i for BCFM was set at 129 bushels while other values of r_i remained unchanged. In the solution to this problem, damaged kernels had a shadow price of $50 per bushel.

Another blending linear program—No. 13—was run for a firm producing thirteen different products: No. 1 through No. 5 corn; two mixed feeds; and corn for storage, dry millers, distillers, exporters, wet millers, and food processors.[2] In addition to corn, the firm used oats and soybean oil meal. The only corn characteristic having a nonzero shadow price in the optimal solution was corn weight. Its shadow price was 9.5¢ per pound, which is much larger than the shadow prices for weight in table 2.

The next section applies these results to evaluation of corn grades.

Application of ICM to Corn Grades

Two questions must be considered in establishing or evaluating a grading system. What characteristics of the product should be included? How should the information be reported? Included under this second question is the question: How should the information be condensed for reporting? Should it be condensed into a numerical grade using the lowest-quality-characteristic method now used for corn? (Suppose a lot of corn meets the requirements for No. 1 corn on two characteristics, for No. 2 corn on two others, and for No. 3 corn on a fifth characteristic. That lot of corn then is graded No. 3, based on the lowest-quality characteristic.) Should it be condensed into a composite (numerical) grade as described by Hyslop? Marginal implicit prices of characteristics can be used in determining answers to both questions. The following discussion focuses on the reporting issue, but many of the points presented also have implications for the first question.[3]

[2] The specifications for these last products were averages obtained from surveys of corn processors.

[3] This is not intended to be a thorough evaluation of corn grades but is only intended to illustrate how ICM may be used to evaluate grades and standards. More details are available in Martin.

Given a list of characteristics, let us say that a grading system is sign-optimal for a given firm with respect to that list (*a*) if the list of grading characteristics having positive marginal implicit prices for the firm is the same as the list of characteristics that raise grade (e.g., No. 3 to No. 1) when their yield per bushel rises; (*b*) if the list of grading characteristics having negative marginal implicit prices for the firm is exactly the same as the list of characteristics that lower grade (e.g., No. 1 to No. 2) when their yields per bushel rise; and (*c*) if the list of characteristics having zero marginal implicit prices is the same as the list of characteristics whose variations have no effect on grade. These three conditions can be summarized in one condition: for every characteristic, varying the yield per bushel of the characteristic has the same effect on grade as on per unit value of the commodity to the firm.

From the standpoint of the individual firm, sign-optimality certainly is a desirable characteristic. (Strictly speaking, no numerical grading system can be sign-optimal for any firm because of the ranges allowed in each grade.) The linear programming results presented earlier suggest serious problems in attaining sign-optimality. The present corn grading system is not sign-optimal for a firm that finds itself in any one of the situations analyzed in the thirteen different problems. For example, marginal implicit prices for moisture are zero in every solution, yet variations in moisture content affect grade. This violates property (*c*). Further, it is not possible to find a subset of the characteristics currently used in grading corn that provide a sign-optimal numerical grading system for all of these thirteen situations.

Knapp made a linear programming study of the corn-blending and merchandising operations of an Iowa regional grain marketing cooperative. For each of some 190 bins of corn, he determined per bushel net marginal value product (NMVP) as the excess of per bushel MVP over the market price of corn having the same characteristics as the corn in the bin. Adding to each NMVP the price of corn having the same characteristics as the corn in the bin yields the MVP for the corn in the bin. Ranges in values of MVPs are shown in table 3. MVP equals $\Sigma y_i \Delta r_i$ as defined in equation (24).

A grading system that was sign-optimal would not yield results like these. Under a

Table 3. Ranges in Values of MVPs for Bins of Different Grades of Corn

Grade	MPV range, $/bu.
1	1.0785 to 1.0978
2	1.040 to 1.1267
3	1.0215 to 1.0993
4	1.0015 to 1.0874
5	1.0000 to 1.07852
Sample	1.02074 to 1.08815

Source: Knapp.

sign-optimal system, the highest MVP for one grade of corn would be less than the lowest MVP for the next better grade of corn. In this table, the highest MVP for sample grade corn (the lowest grade) exceeds the lowest MVP for every one of the higher grades of corn, and the highest MVP for sample grade corn exceeds the highest MVP for No. 4 grade corn. The firm could afford to pay a higher price for some sample grade corn than for some corn of grades 1, 2, 3, 4, and 5. The highest MVP for No. 3 grade corn exceeds the lowest MVPs for No. 1 grade corn (the highest grade) and No. 2 corn. The firm could afford to pay more for some No. 3 corn than for some No. 1 and No. 2 corn. In summary, the firm could afford to pay more for some lots of corn of one grade than for some lots of corn of a higher grade.

These linear programming solutions support the hypothesis that it is impossible to develop a numerical grading system that will be sign-optimal for a substantial number of firms. Additional evidence to support this hypothesis is presented by Martin. One hundred ninety-seven country elevators and ninety-one firms in five different corn-using industries were asked to rank each of nine characteristics of corn in order of importance to itself. The ranks varied substantially among industries and also within industries, as shown in tables 4 and 5. For the firms in each industry, a pooled (or average) rank was computed for each characteristic. Table 4 shows substantial variation in the relative importance of many of the characteristics. Total damage, for example, varies from second in importance for country elevators to sixth in importance for dry millers. Moisture varies from second in importance for exporters and feed manufacturers to eighth for wet millers.

Substantial variation also existed among firms in the same industry. To measure the extent of agreement among the ranks assigned by two firms in the same industry, one can use a coefficient of rank correlation. To measure the extent of agreement among the ranks assigned by several firms, Kendall's coefficient of concordance, W, can be used. Its value ranges from zero, indicating no agreement or independence of the rankings, to one, indicating perfect agreement among the rankings. A coefficient of concordance was computed for the firms in each corn-buying industry. The values of W are presented in table 5. Each value of W is significant at the 1% level; the hypothesis of independence of rankings is therefore rejected for each industry. However, substantial disagreement existed within each industry as evidenced by the difference of each value of W from one.

The difficulty in attaining sign-optimality for all firms comes from, among other things, variations over time and among firms in input and output prices, stocks, technologies used, and the characteristics of the final products. Sign-optimality is a rather modest requirement for a

Table 4. Pooled Ranks of Importance of Corn Characteristics

Characteristic	Country Elevator	U.S. Exporter	Wet Miller	Dry Miller	Distiller	Feed Manufacturer
Musty, sour, heating	4	1	1	1	1	1
Weevily corn	7	6	2	2	5	6
Heat damage	6	4	4	4	2	4
Rodent excreta	8	7	3	3	6	7
Total damage	2	3	5	6	3	3
Foreign material	3	5	6	7	7	8
Moisture	1	2	8	5	4	2
Test weight	5	9	9	8	8	5
Stress cracks	9	8	7	9	9	9
No. of responses	197	19	11	19	11	31

Table 5. Coefficients of Concordance for Corn Quality Rankings

Group	W
Dry millers	0.688
Distillers	0.661
Wet millers	0.527
Exporters	0.340
Feed manufacturers	0.333
Country elevators	0.281

grading system; yet our results show the present corn-grading system cannot achieve it, nor can any other system of numerical grades achieve it.

We suggest an alternative to numerical grades for reporting the information now obtained in grading corn: the specified-order method of reporting. This method comes closer to achieving sign-optimality than any system of numerical grades.

Suppose we have a carload of corn in which (*a*) test weight per bushel is 55.0 pounds, (*b*) moisture content is 16.2%, (*c*) BCFM is 2.5%, (*d*) total damaged kernels are 4.1%, and (*e*) heat-damaged kernels are 0.1%. According to current U.S. corn standards, this grades No. 3. Yet the corn is No. 2 on characteristics (*a*), (*c*) and (*d*), and No. 1 on characteristic (*e*). The specified-order method of describing this corn would not report that this is No. 3 corn. It would list the numerical values of all five characteristics in some specified order. Suppose the specified order were the order listed in (*a*) through (*e*). Then this would be described as a carload of "55.0-16.2-2.5-4.1-0.1 corn." Basically, this is a nongrading method because no grade is assigned by an official grader. The official "grader" would make the same tests that he does now. But instead of condensing these five numbers into one numerical grade, he would simply report all five numbers in a specified order.

The specified-order method could be used with one base specification being used for purposes of price reporting and futures trading. Present specifications for U.S. No. 2 corn for test weight (54 pounds), broken corn and foreign material (3%), and total damaged kernels (5%), and the moisture specification for U.S. No. 1 (14%) would be the most acceptable base grade, according to the responses to corn industry questionnaires.

Although the specified-order method would abolish numerical grades, grain dealers could continue to blend to specifications. The base grade probably would become the typical blending specification, but other characteristic specifications could be requested by buyers. Because the base grade is suitable for storage and almost all uses, premiums probably would not be paid for corn exceeding the base specifications. Buyers would have the option of using flexible discounts for lots not meeting the base grade. Implicit characteristic prices derived from linear programming models could be used to determine discount schedules for characteristics, although custom and competition probably would limit the frequency of changing the discount schedules.

We will not go into the question of selecting the characteristics to be included in a grading system except to note this. The second paragraph of this section listed three properties of a sign-optimal grading system. The last one was: the characteristics having zero marginal implicit prices have no effect on grade. This property could be used to determine which characteristics to exclude from a grading system: those characteristics having zero (or small) marginal implicit prices for a large number of firms under a variety of market conditions.

Application of ICM to Product Line Selection

Consider a competitive firm producing goods that are inputs to other firms, e.g., a cattle feeder selling to a packer. Because the firm is in a competitive industry, it cannot affect the price it receives by varying the amount it produces. It can, however, affect the price it receives by varying the "quality" of its output. What quality of product should it produce for maximum profit? Let us measure quality by the amounts of various characteristics contained in one unit of product. Define p and q as price and quantity of product; define x_i as the amount of the ith characteristic in one unit of product; define $c(q, x_1, x_2, \ldots, x_n)$ as the average cost function; and define $p(x_1, x_2, \ldots, x_n)$ as the function relating quality to price. Then the firm's profit is

$$\pi = qp(x_1, x_2, \ldots, x_n) - qc(q, x_1, x_2, \ldots, x_n).$$

One first-order condition for profit maximization is the familiar "price equals marginal cost" condition:

$$\partial \pi / \partial q = p - (q \partial c / \partial q + c) = 0.$$

To determine the profit-maximizing level of x_i,

$$\partial \pi / \partial x_i = q \partial p / \partial x_i - q \partial c / \partial x_i = 0.$$

If $q \neq 0$, it follows that

$$\partial p / \partial x_i = \partial c / \partial x_i.$$

The equilibrium level of x_i is achieved when the marginal effect of x_i on price equals the marginal effect of x_i on average production cost.

Summary and Limitations

The model presented here is not a theory of prices; a theory of prices deals with the supply side as well as the demand side of the market. But ICM deals only with demand for input characteristics and not with supply of input characteristics. The model presented here complements existing theories. Suppose, for example, an unfortunate combination of floods and droughts drastically reduces the corn crop. Existing theory tells us how the resulting shift in supply of corn affects prices of corn. Equation (5) simply states that the price (whatever it may have been) of a grade of corn before the shift in supply exactly equalled the total marginal monetary values of the characteristics of the corn for each firm who purchased it. And it states that the same equality prevails for the price (whatever it may be) after the shift in corn supply. Equation (5) and the linear programming model suggest how the marginal implicit prices can be estimated both before and after the shift in corn supply.

In their statistical studies, Hyslop and Waugh (1928, 1929) obtained some negative implicit prices. Negative implicit prices are consistent with ICM and with observation. Some product characteristics may be "inferior characteristics," that is, their presence in any amount reduces the value of a product. Other characteristics may have positive marginal prices up to a point but negative marginal prices after that point. Increasing the length of a truck may increase the value of the truck up to some point because it provides more cargo room. But beyond that point, additional length may reduce the value of the truck because it makes it too long to fit into one's garage, too long to negotiate street corners, and dangerous to drive.

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Impact of Socioeconomic Factors on Consumption of Selected Food Nutrients in the United States

John Adrian and Raymond Daniel

The impacts of socioeconomic characteristics of the household and its constituents on consumption of protein, carbohydrate, fat, vitamin A, calcium, iron, thiamine, and vitamin C were estimated. Data from 6,950 households located in the contiguous states were utilized to specify consumption relationships. Socioeconomic factors considered were: income, degree of urbanization, race, educational attainment of the homemaker, stage of the household in the family life cycle, family size, meal adjustment, and employment status of the homemaker. Income had a positive impact on the consumption of all nutrients except carbohydrate. However, nutrient consumption responsiveness to income was relatively small.

Key words: consumption, food nutrients, households, income, United States.

A greater awareness of "consumerism" and increased public interest in nutritional levels has heightened the need for a more complete understanding of nutrient consumption patterns. Despite the availability of a plentiful and varied food supply at relatively acceptable prices, nutrient consumption levels may not be sufficient. Unequal distribution of economic and other resources, differences in sociological factors, and the diversity and complexity of channels used to purchase food have resulted in variations in the consumption of food nutrients by households.

Food consumption research has focused on specifying the relationship between selected socioeconomic factors and the traditional quantity and expenditure measures (Burk 1961, 1968; George and King; Price; Thomas). However, these two approaches limit inference relative to the nutritional status of household diets, that is, a large quantity of food or a large expenditure for food may not generate acceptable levels of nutrient consumption. Therefore, specification of the impact of various socioeconomic characteristics of the household on nutrient consumption could provide insight relative to nutrient consumption patterns of households in the United States. For instance, the relationship between income distribution and nutrient consumption by American households can be evaluated, and knowledge of these relationships can be utilized to develop nutrition education programs by focusing attention on households with low levels of nutrient consumption. Since certain commodities or commodity groups are primary sources of specific nutrients, specification of these relationships can also provide information concerning future demand trends which will directly affect the types of agricultural products produced and marketed in the United States.

Several studies have focused on specifying the influence of household income and other socioeconomic characteristics on nutrient consumption, but most of these have been limited to localized areas or particular groups of people (Babcock; Einstein and Horstein; Kelsay; Madden and Yoder). Generally, these studies noted significant variations in nutrient consumption with respect to income, education, and race. National and regional studies conducted primarily by the U.S. Department of Agriculture have involved only tabular analyses. The purpose of this paper is to analyze estimates of the effects of selected characteristics of the household and its constituents on food nutrient consumption in the United States.

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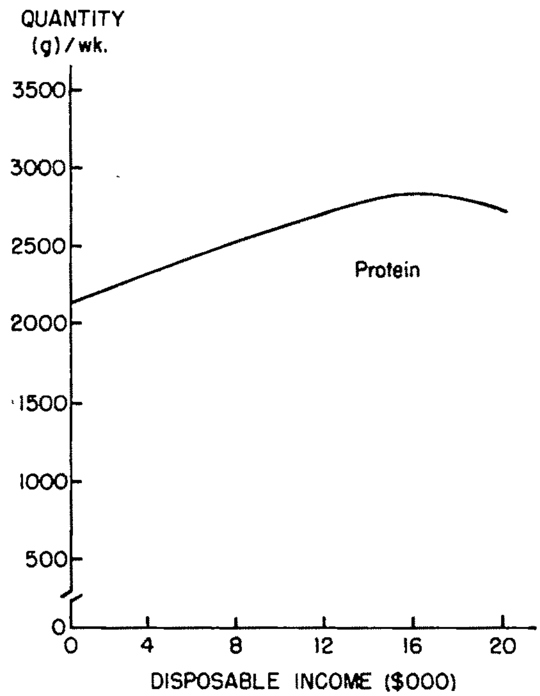

Figure 1. Protein income-consumption relationship

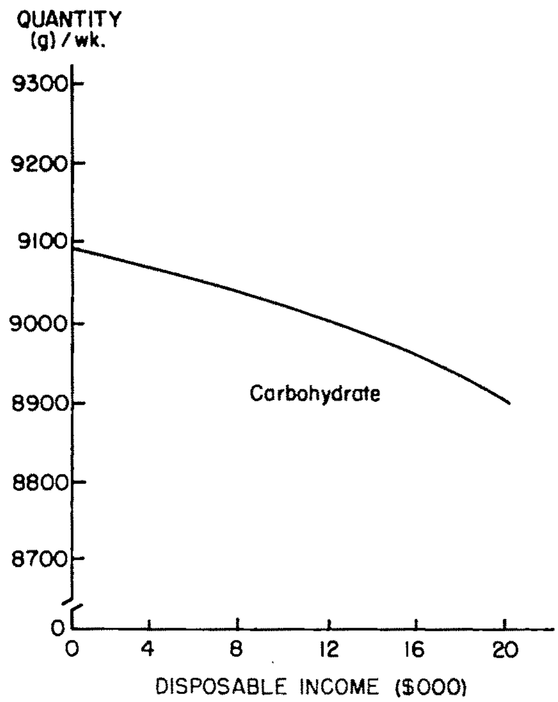

Figure 2. Carbohydrate income-consumption relationship

Data and Model

Data from the 1965–66 nationwide household food consumption survey conducted by the Consumer and Food Economics Research Division, USDA are utilized. The original USDA survey included approximately 7,500 households located in the contiguous states. This analysis includes data from usable schedules for 6,950 households.[1]

The quantities of the respective nutrients consumed per household are computed by multiplying the quantity of each food consumed by the household times the percent of each nutrient available in each unit of food. The summation of this product over all foods for each respective nutrient provides an approximation of the quantity of each nutrient available for consumption by the household per week.[2] Nutrients included in this analysis are protein, carbohydrate, fat, vitamin A, calcium, iron, thiamine (vitamin B_1), and vitamin C.[3]

The economic and sociological characteristics of the household hypothesized to influence consumption of these nutrients are income, degree of urbanization, race, educational attainment of the homemaker, stage of the household in the family life cycle, family size, meal adjustment, and employment status of the homemaker.

Multiple regression analysis is used to estimate the following relationships for households in the United States.[4] The statistical model utilized is

$$\begin{aligned} Q_i = a &+ b_1Y + b_2Y^2 + b_3U_1 + b_4U_2 \\ &+ b_5R_1 + b_6R_2 + b_7E_1 + b_8E_2 + b_9E_3 \\ &+ b_{10}L_1 + b_{11}L_2 + b_{12}L_3 + b_{13}L_4 \\ &+ b_{14}L_5 + b_{15}S + b_{16}M + b_{17}F + u, \end{aligned}$$

where Q_i = quantity of the ith nutrient ($i = 1, \ldots, 8$) consumed per household per week, that is, Q_1–Q_3 = grams of protein, carbohydrate, and fat; Q_4 = international units of vitamin A; and Q_5–Q_8 = milligrams of calcium, iron, thiamine, and vitamin C; Y = an-

[1] The 550 households were eliminated from the analysis because relevant income, race, and other data were missing.

[2] The quantity of food and nutrients consumed by the household represents total quantity available for consumption and not necessarily the quantities eaten by household members. Some food was discarded in the kitchen and at the table. Nutrient supplements (vitamins, etc.) were not included in the survey so some households could have consumed larger quantities of some nutrients. Average nutritional content of the various foods was adjusted for loss of nutrients during preparation (USDA 1969, pp. 1–4).

[3] Estimates for animal protein, vegetable protein, food energy, riboflavin, and niacin were also made (Adrian).

[4] The same model was estimated for the four major regions of the United States. The results of these models deviated little from the aggregate model (Adrian).

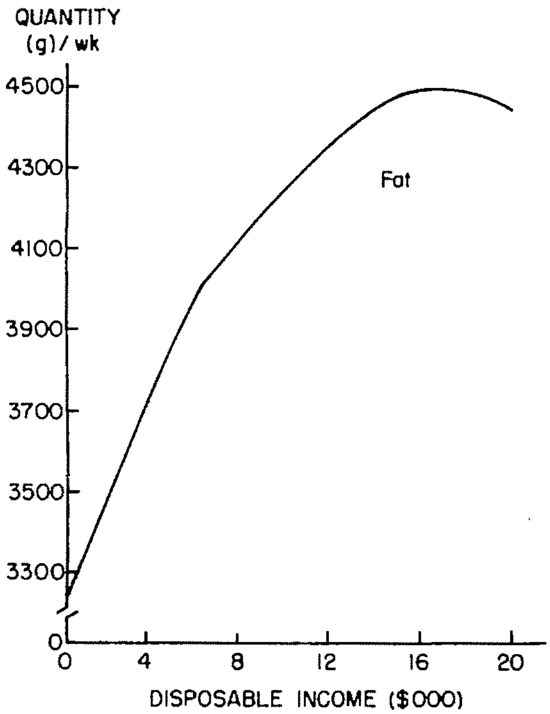

Figure 3. Fat income-consumption relationship

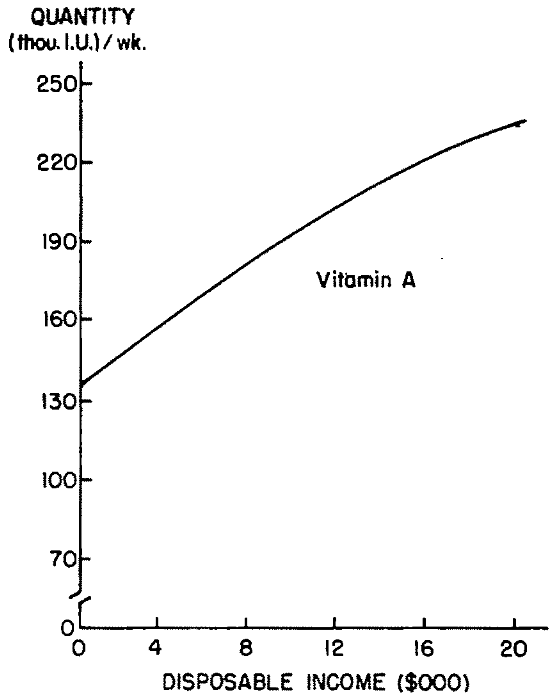

Figure 4. Vitamin A income-consumption relationship

nual household disposable income, $1,000;[5] U_0–U_2 = degree of urbanization (rural farm, urban, and rural nonfarm); R_0–R_2 = race of the household (black, white, and other); E_0–E_3 = educational attainment of the homemaker (high school, grade school, some college, and college graduate); L_0–L_5 = stage of the household in the family life cycle: average age of the children is between six and twelve years—stage 3; no children are present and the housewife is forty years of age or less—stage 1; average age of the children is less than six years—stage 2; average age of the children is between twelve and seventeen years—stage 4; average age of the children is over seventeen years—stage 5; and no children are present and the housewife is over forty years of age—stage 6 (consult Lansing and Kish for a more detailed explanation of this variable); S = family size which is the total number of individuals in a household who depend on a common pool of income for their livelihood; M = meal adjustment which represents the influence of home, guest, skipped, and away meals (meal adjustment is computed as the difference between the number of meals each household reported serving and the number of family members multiplied by 21; the 21 represents meal equivalents per week for one household member); and F = employment status of the homemaker (employed and unemployed).[6]

The same socioeconomic behavioral model is used for each nutrient because nutrients are constituent parts of food; therefore, the same factors may affect the consumption of each nutrient.[7] Each nutrient may be affected differently by the various factors, but there are no a priori justifiable reasons to include or delete a variable for any one nutrient estimate.

Consumers purchase the respective nutrients through their allocation of income to various food products. In making this allocation, consumers are assumed to be making decisions which reflect their desire to have and maintain a balanced and adequate diet. This

[5] The income for households was classified in the original data into fourteen classes, ranging from under $1,000 to $25,000 and over. The middle of each range was used as the actual observation for each family within that range except for the $25,000 or more class where $25,000 was used. See Lee and Phillips for an example of using this approach in estimating Engel curves.

[6] Zero-one dummy variables are utilized to analyze the impact of urbanization, race, educational attainment, family life cycle, and employment status of the homemaker. The initial class in each category, as indicated, is excluded to avoid singularity.

[7] Rather than scale the dependent variables to account for variations in household size and composition implicitly, these factors are entered as independent variables in the models and their impacts are estimated explicitly. Multicollinearity was not encountered.

assumption is not without exception because some of the food consumed by individuals is based on nonnutritive criteria such as habit or impulse consumption. Nevertheless, consumers must make some effort to consume at least minimal quantities of the basic nutrients for the sustenance of life. On the other hand, nutrient consumption is limited by the food consumption capacity of members of the household and also, the desire or necessity of purchasing other goods and services. Thus, the ratio of the quantity of the nutrient consumed to disposable income would not be constant at each subsequent level of income, i.e., a curvilinear relationship is expected. Therefore, a quadratic functional form is utilized to estimate the respective nutrient consumption relationships.[8]

Results

The models postulated to explain variations in household nutrient consumption are acceptable considering the use of cross-section data. Variations in the independent variables included in the models explain more than 50% of the variation in household consumption of protein, carbohydrate, fat, calcium, iron, and thiamine (tables 1 and 2). Similarly, these variables explain 18% and 30% of the variation in household consumption of vitamins A and C, respectively.

Income

Annual household disposable income is a significant factor affecting household consumption of protein, fat, vitamin A, calcium, iron, thiamine, and vitamin C (tables 1 and 2). Consumption of all of these nutrients except calcium and thiamine increases initially, peaks, and declines with successive positive increments of income as is indicated by the significant positive and negative signs of the income and income-squared coefficients. In the models for calcium and thiamine consumption, income coefficients are positive and significant, but the income-squared coefficients have relatively large standard errors. Standard errors in the carbohydrate equation are larger than the estimated income coefficients.

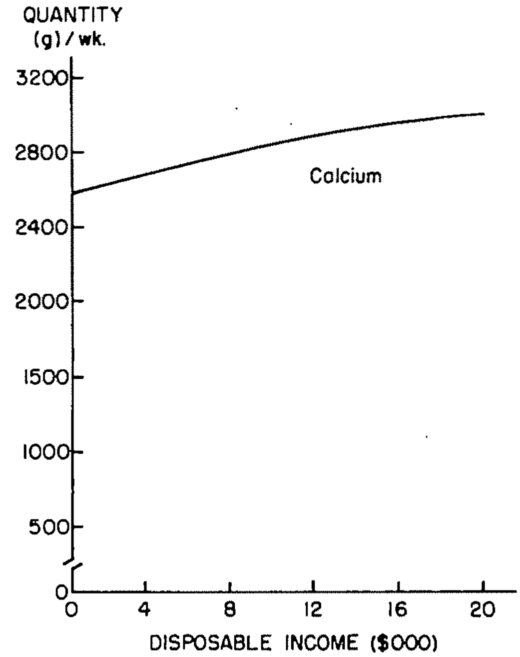

Figure 5. Calcium income-consumption relationship

The relationship between disposable income and consumption of the respective nutrients is further illuminated by the income-consumption relationships illustrated in figures 1–8. These estimates were derived from the respective food nutrient consumption estimates by shifting income from level to level and holding socioeconomic variables other than income at their means.

Nutrient consumption is not highly responsive to income changes as is indicated by the relatively small elasticities in table 3.[9] However, the elasticities do indicate positive responsiveness at all selected income levels for fat, vitamin A, calcium, and vitamin C. Similarly, positive consumption responses are noted for protein, iron, and thiamine consumption at all selected income levels except $20,000 where the response is negative. Over the income spectrum considered, the largest responses occur for protein, fat, iron, thiamine, and vitamin C at the $8,000 level and for vitamin A and calcium at the $12,000 level.

[8] Several alternative functional forms were utilized to determine the functional relationship between income and household consumption of the respective nutrients. The functional forms evaluated, *ex post*, were: linear, semilogarithmic, double-logarithmic, cubic, and transcendental. Based on the coefficients of determination (R^2's) and statistical significance of income coefficients for these functional forms, the quadratic form appeared to be the most appropriate for all nutrients.

[9] Inherent in the analysis of income elasticities for cross-section data is the assumption that a household at one income level will consume as much of a certain nutrient as does a household at a different income level if its income is increased to the new level.

Table 1. Consumption Relationships for Protein, Carbohydrate, Fat, and Vitamin A, Spring 1965–66

Variable	Protein (g.)	Carbohydrate (g.)	Fat (g.)	Vitamin A (I.U.)
Intercept	689.41	3,112.23	1,500.43	84,031.15
	(71.71)[a]	(281.71)	(116.73)	(11,335.83)
Income	80.45	−8.68	130.61	7,013.68
	(7.77)	(30.53)	(12.65)	(1,228.40)
Income squared	−2.32	0.03	−3.66	−131.81
	(0.36)	(1.39)	(0.58)	(56.08)
Urban	−326.36	−2,386.82	−756.21	1,967.44
	(32.57)	(107.19)	(44.42)	(4,313.14)
Rural nonfarm	−262.04	−1,442.47	−492.47	−13,886.43
	(32.57)	(127.95)	(53.02)	(5,148.55)
White	153.89	437.98	24.48	−22,962.35
	(35.71)	(140.30)	(58.14)	(5,645.54)
Other	177.54	994.30	−264.22	1,962.88
	(80.66)	(316.88)	(131.31)	(12,751.09)
Grade school	−38.60	266.02	−21.81	−5,155.61
	(26.76)	(105.12)	(43.56)	(4,229.89)
Some college	11.04	36.56	−33.86	3,083.05
	(36.41)	(143.04)	59.27	(5,755.97)
College graduate	−76.64	−321.58	−266.99	−1,344.34
	(44.84)	(176.14)	72.99	(7,087.81)
Stage 1	−255.08	−387.19	−342.03	−31,373.44
	(63.74)	(250.42)	(103.77)	(10,076.88)
Stage 2	−239.96	−1,150.52	−361.96	−15,647.90
	(35.52)	(139.56)	(57.83)	(5,615.88)
Stage 4	207.72	439.23	343.82	−2,463.06
	(39.71)	(156.02)	(64.65)	(6,278.01)
Stage 5	58.18	−377.97	85.00	−1,485.06
	(64.89)	(254.93)	(105.64)	(10,258.14)
Stage 6	−273.21	−1,055.02	−526.87	−16,283.07
	(44.50)	(174.83)	(72.42)	(7,035.06)
Family size	520.29	2,211.25	723.53	26,523.20
	(8.17)	(32.09)	(13.24)	(1,291.34)
Meal adjustment	31.72	107.20	46.16	1,777.21
	(0.74)	(2.92)	(1.21)	(117.41)
Employment status	25.01	208.42	92.65	−2,936.05
	(24.41)	(95.91)	(39.74)	(3,859.31)
R^2	0.64	0.66	0.59	0.18
F-ratio	725.79	786.72	597.00	86.64

[a] Figures in parentheses are standard errors.

Other Variables

Degree of urbanization may reflect the composite impact of such factors as the potential for home food production, accessibility to diverse types of stores including food stores providing a wide variety of foods, distinctions in the social, cultural, and economic environment such as occupational and educational opportunities, and the effects of mass media. The results indicate that farm households consume more of all nutrients except vitamins A and C than do urban or rural nonfarm households (tables 1 and 2). Vitamin A consumption is greater for rural farm than for rural nonfarm families. Vitamin C consumption does not vary significantly by degree of urbanization of the household.

The results suggest that nutrient consumption differs by race of the household (tables 1 and 2). Black households consume less carbohydrate, calcium, and thiamine than do either white or other race households. Also, black households consume less vitamin C, iron, and thiamine and more fat than do other race households. Similarly, they consume more protein and less vitamin A than do white households.

An inverse relationship is noted between educational attainment of the housewife and carbohydrate, fat, iron, and thiamine consumption (tables 1 and 2). Conversely, vita-

Table 2. Consumption Relationships for Calcium, Iron, Thiamine, and Vitamin C, Spring 1965–66

Variable	Calcium (mg.)	Iron (mg.)	Thiamine (mg.)	Vitamin C (mg.)
Intercept	7,992.01	141.50	11.51	539.99
	(919.48)[a]	(15.01)	(1.22)	(116.00)
Income	285.13	7.09	0.35	160.05
	(99.64)	1.63	(0.13)	(12.57)
Income squared	−6.81	−0.19	−0.01	−3.67
	(4.55)	(0.07)	(0.01)	(0.57)
Urban	−4,636.68	−81.96	−7.18	20.65
	(349.85)	(5.71)	(0.46)	(44.14)
Rural nonfarm	−2,815.85	−59.32	−5.03	−6.43
	(417.61)	(6.82)	(0.55)	(52.69)
White	4,289.54	−1.21	−1.42	107.18
	(457.93)	(7.48)	(0.61)	(57.77)
Other	3,377.15	36.84	0.89	441.13
	(1,034.28)	(16.88)	(1.37)	(130.48)
Grade school	255.60	5.09	1.30	−163.61
	(343.10)	(5.60)	(0.46)	(43.29)
Some college	778.81	−0.18	−0.29	191.63
	(466.88)	(7.62)	(0.62)	(58.90)
College graduate	954.64	−19.30	−0.89	104.88
	(574.91)	(9.39)	(0.76)	(72.53)
Stage 1	−4,421.91	−8.58	−0.67	−438.09
	(817.37)	(13.34)	(1.08)	(103.12)
Stage 2	−1,422.03	−33.00	−2.51	−273.56
	(455.52)	(7.44)	(0.60)	(57.47)
Stage 4	1,361.44	35.50	3.30	211.33
	(509.23)	(8.31)	(0.68)	(64.24)
Stage 5	−1,911.92	13.05	0.64	72.88
	(832.07)	(13.58)	(1.10)	104.97
Stage 6	−4,362.02	−24.04	−2.57	−231.33
	(570.63)	(9.32)	(0.76)	(71.99)
Family size	5,584.65	109.39	9.59	340.28
	(104.74)	(1.71)	(0.14)	(13.21)
Meal adjustment	289.28	5.99	0.48	27.65
	(9.52)	(0.16)	(0.01)	(1.20)
Employment status	416.91	6.78	0.64	−7.60
	(313.04)	(5.11)	(0.42)	(39.49)
R^2	0.56	0.61	0.65	0.30
F-ratio	527.53	647.74	751.93	176.57

[a] Figures in parentheses are standard errors.

Table 3. Nutrient Income Elasticities

	Selected Income Levels					
Nutrient[a]	$2,000	$4,000	$8,000	$12,000	$16,000	$20,000
Protein	0.059	0.098	0.126	0.103	0.034	−0.084
Fat	0.066	0.109	0.142	0.119	0.049	0.072
Vitamin A	0.067	0.115	0.172	0.188	0.173	0.130
Calcium	0.019	0.034	0.050	0.051	0.037	0.009
Iron	0.027	0.046	0.065	0.059	0.031	−0.020
Thiamine	0.016	0.028	0.038	0.032	0.012	−0.024
Vitamin C	0.148	0.233	0.299	0.283	0.208	0.078

Note: Elasticities are affected by the functional form selected to derive estimators of the coefficients. These elasticities were computed from a quadratic function with all factors except income held at mean values and the quantity of the respective nutrient consumed allowed to vary only in response to changes in disposable income.

[a] Elasticities for carbohydrate are excluded because the relationship between income and quantity consumed was not significant at the 0.05 level.

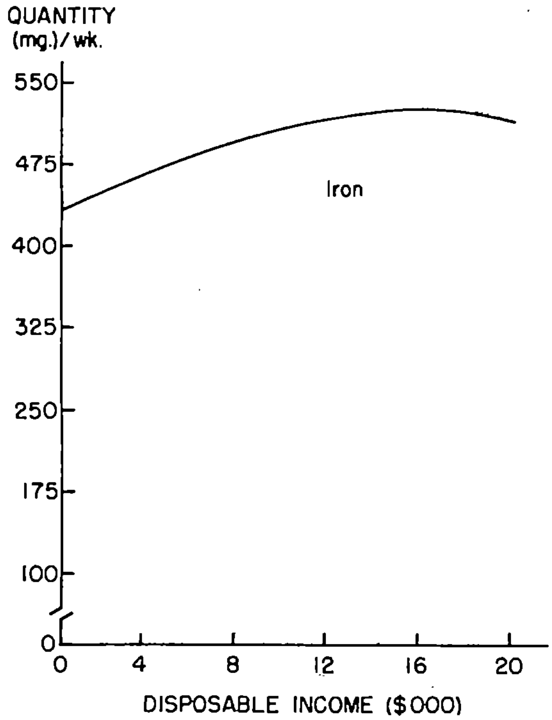

Figure 6. Iron income-consumption relationship

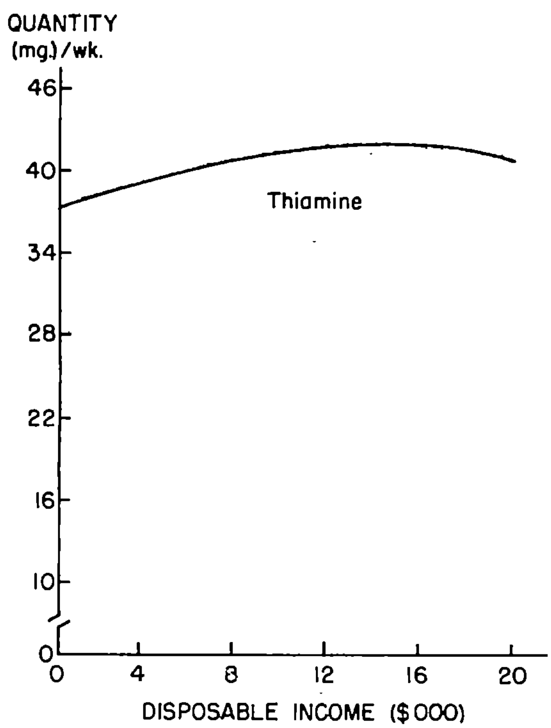

Figure 7. Thiamine income-consumption relationship

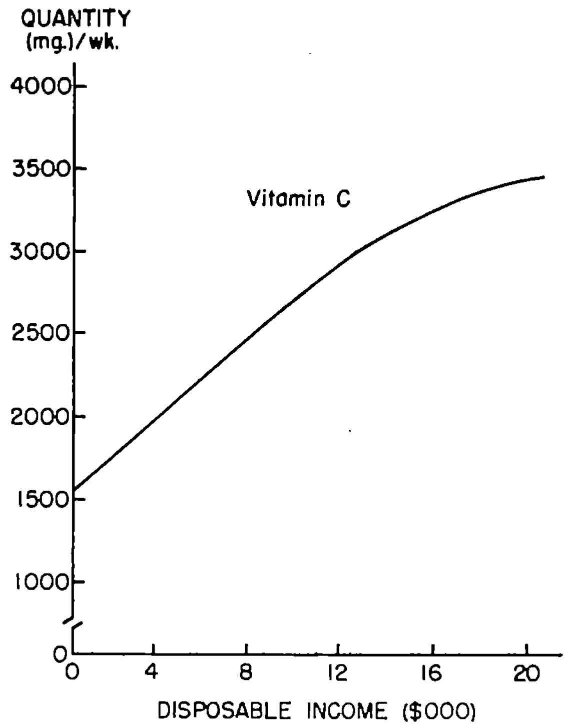

Figure 8. Vitamin C income-consumption relationship

min C consumption tends to increase with additional formal education of the housewife. Similar tendencies are not present for protein, calcium, or vitamin A consumption.

The age of the housewife and the presence and average age of the children in the household, as represented by the family life cycle variable, influence food nutrient consumption (tables 1 and 2). The results suggest that households with children under six years of age (stage 2) and households without children and with the housewife over forty years of age (stage 6) consume smaller quantities of all nutrients than do households with the average age of the children between six and twelve years (stage 3). Households with no children and a housewife under forty years of age (stage 1) consume less of all nutrients except carbohydrate, iron, and thiamine than do base households (stage 3). Households with children from twelve to seventeen years (stage 4) consume the largest quantities of all nutrients except vitamin A.

Family size and meal adjustment affect consumption of the respective nutrients positively, as was expected (table 1 and 2). Thus, an increase in family size is associated with an increase in nutrient consumption. Also, an in-

crease in either home or guest meals increases nutrient consumption, while an increase in either skipped or away from home meals has the opposite effect.

Consumption of carbohydrate and fat is greater for households with an employed housewife (tables 1 and 2). Other differences in nutrient consumption between households with employed and unemployed housewives are not significant.

Summary and Conclusions

Several characteristics of the household and its constituents influence household consumption of food nutrients. Income is a significant positive factor affecting the consumption of all nutrients except carbohydrate. Increases in consumption, however, are not proportional to increases in disposable income. Nutrient consumption responsiveness to income is relatively small with the greatest responsiveness noted in the \$8,000 to \$12,000 income range. This implies that future income increases (in real terms) above this range will have a smaller impact on food consumption in the United States.

The positive income elasticities add credence to policy aimed at generating nutritionally adequate diets through income transfers, but their relatively small magnitudes indicate that nutrient consumption is not highly responsive to income. Therefore, if the primary goal of the policy is to alleviate nutritional deficiency, direct food transfers may be more effective than income transfers.

An analysis of the impact of other socioeconomic factors reveals some significant differences in consumption of the various food nutrients. Urban and rural nonfarm households consume smaller quantities of all nutrients except vitamins A and C than do farm households. Thus, a continued trend toward a more urban society in the United States will result in a possible relative decline in consumption of all nutrients except vitamins A and C. This occurrence is most likely the result of decreased home food production by families in urban areas and decreased food consumption because of more sedentary work habits. Similarly, black households consume less carbohydrate, calcium, and thiamine than do either white or other race households. Also, the more educated housewives seem to serve meals to their families with less carbohydrates and fats and more vitamin C. Finally, households with employed housewives consume more carbohydrates and fats. These results indicate that food nutrition programs could possibly be more effective if directed toward urban, less educated, black households.

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Analyzing Hog Production Strategies with a Simulation Model

Malcolm J. Blackie and J. Barry Dent

Simulation modelling has attracted considerable farm management research interest in recent years, yet the on-farm use of simulation models has been limited. A simulation model for hog production has been developed as part of an information system which may assist hog farm managers both in choosing between competing management strategies and also in implementing any chosen plan. The process involved in selecting the most suitable management strategy is illustrated using data from several hog units. The incorporation of the model into an information system ensures that the model is accessible to farm managers and their advisers.

Key Words: hog production, information systems, simulation model.

Simulation as an investigative tool in farm management has, as yet, failed to fulfill many early expectations (Anderson). This result is attributable largely to researchers' enthusiasm for the model-building aspect of simulation research which has not been matched by corresponding effectiveness in using the models for guidance of real world decision making (Dobson). For a model to be used effectively by farm managers, it needs not only to mimic accurately the real system but also to be accessible to managers. Effective communication between the model and its intended users is most readily obtained by incorporating the model into an information system which includes a comprehensive data collection and transmission service (Blackie). The data required must be readily obtainable by the manager and the information returned from the information system must be in a form that is easily understood by the farm manager.

The purpose of this paper is to discuss the application of a simulation model which may be used by hog farm managers to assess possible outcomes from alternative management policies (Blackie and Dent). This paper reports the results from using the model to evaluate three specific management strategies. The first strategy deals with bred-gilt production, and the second and third involve low and ultrahigh density feeding policies, respectively. Each strategy reflects current farmer interest in reducing feed costs.

The Hog Simulation Model

Efforts in computer simulation have been the subject of a number of recent reviews, a phenomenon which reflects the growth of interest in this area of farm management research (Blackie, Eisgruber, Kennedy, Nelson, Rowe). The computer model described in this paper is incorporated into a business information system which is designed to assist hog farm managers in planning their businesses and in controlling and reviewing the plans. A structure diagram of the decision process involved in using this information system is shown in Figure 1.[1] Information on the hog farm is collected by the farm manager with the assistance of an adviser. These data describe the unit in terms of hog numbers, feeding requirements, expectations of future prices and costs, and future management policies.[2] The

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[1] The information system illustrated in this paper was developed by the authors at Nottingham University, England. It is currently being introduced in Britain by one of the major animal feed suppliers and is on trial in New Zealand (Looker).

[2] To illustrate briefly the data requirements of the model, a farm manager involved solely in fattening hogs for slaughter would need to provide the following information: (*a*) hogs on hand (divided roughly into 5 kg weight classes), (*b*) intended hog purchases, (*c*) intended sale weights of hogs, (*d*) expected costs of feed and purchased hogs and expected prices of hogs sold, (*e*) feeding practices, and (*f*) expected feed conversion efficiency.

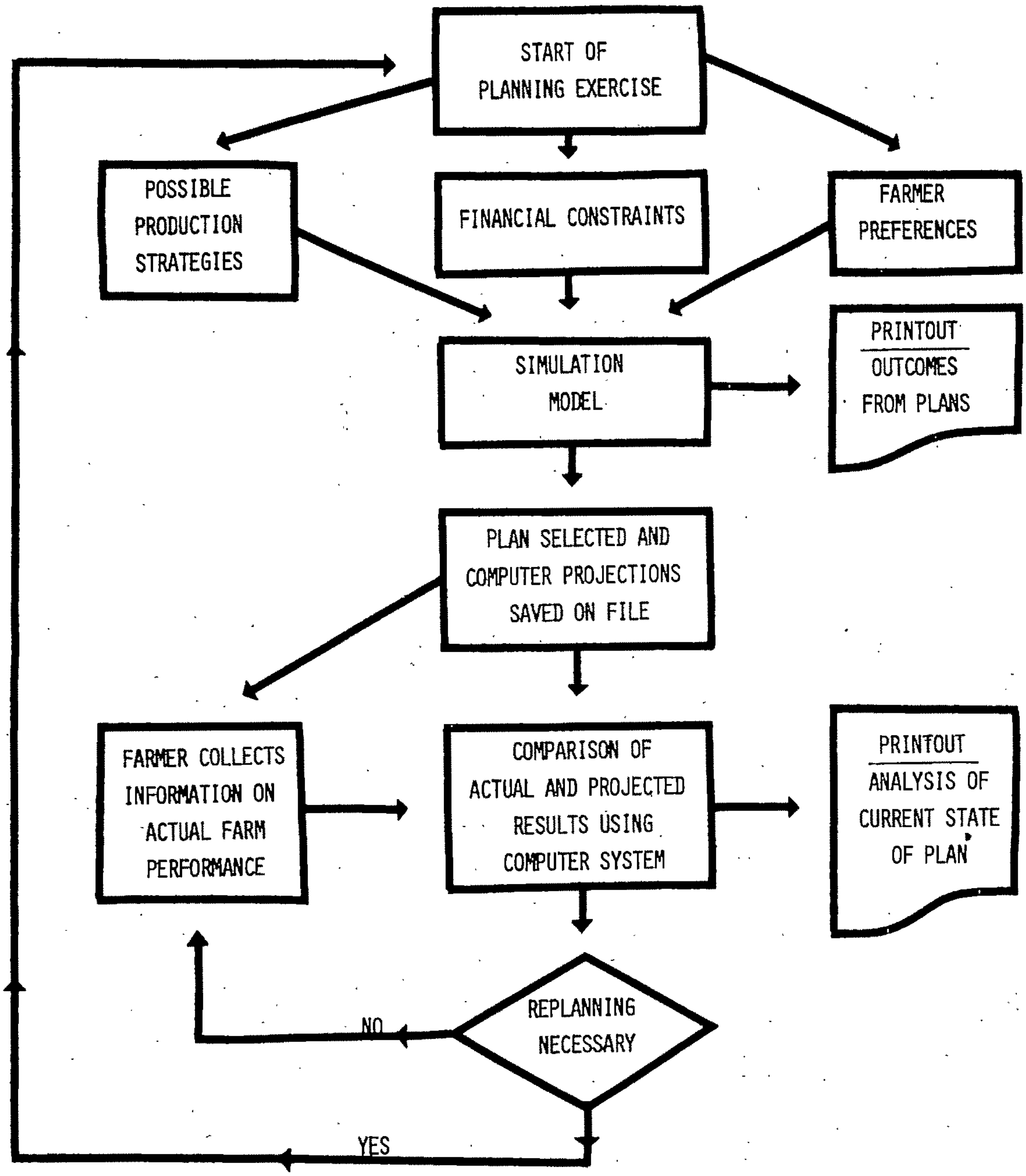

Figure 1. Decision process structure using hog simulation model

data are input to a computer simulation model which produces a detailed forecast of future herd performance. Forecast information includes physical parameters, such as hogs produced, and financial measures such as feed costs, income from hogs sold, and cash flows. The forecast is generally for one year ahead and is divided into thirteen time periods, each four weeks in length. Table 1 includes some of the information contained in the forecast output. Several runs of the model may be made—each run incorporating different assumptions on such factors as feed conversion, capital input requirements, prices and costs, and taxation allowances.

Once a satisfactory forecast has been produced or a strategy selected, the initial input data, termed "setup" data, are stored on a computer file. Every four weeks, the farm manager provides additional data, termed

Table 1. Forecast Output from the Hog Simulation Model

	Fattening House Performance Forecast			Fattening House Cash Flow Forecast			
Period	Hog Sales[a] (83 kg)	Feed Use (tons)	Fill of Fattening House (%)	Hog Sales ($)	Hog Purchases ($)	Feed ($)	Balance ($)
1	36	3.9	78	2,563	382	295	1,886
2	31	3.6	76	2,225	270	285	1,670
3	23	3.6	75	1,623	540	348	735
4	10	4.9	81	1,214	540	488	186
5	22	6.1	84	1,521	434	558	529
6	27	7.5	92	1,934	452	641	841
7	29	7.6	98	2,113	240	599	1,274
8	50	7.6	99	3,515	576	629	2,310
9	50	7.4	96	3,502	572	615	2,315
10	42	7.4	95	2,873	406	615	1,852
11	44	7.0	93	2,988	265	569	2,154
12	17	7.7	99	1,238	215	631	392
13	58	7.1	93	3,932	363	538	3,031
Totals	439	81.4		31,241	5,255	6,811	19,175

[a] Hogs may be sold at three different weights. For simplicity, the example here shows all sales at one weight.

"period input," on the actual performance of his herd. These data are input to a computer program which produces a period performance analysis, including key efficiency factors such as number of births, average litter size, feed conversion, hog sales, or mortality at various stages. A comparison of these factors with the appropriate model projections (targets) generated by the earlier forecast assists the manager in assessing how closely he is following his intended plan. This process provides the manager with a rapid flow of relevant information on the current state of his business.

Validation tests on the model have shown that model target predictions up to six months ahead are sufficiently accurate for business control (Blackie and Dent). Consequently, targets are automatically revised every six months, but the manager may revise his targets whenever he considers it necessary. For example, a change in hog prices could lead to a different marketing strategy or the performance analysis report might indicate that the planned performance was not being achieved.

The data requirements and the operation of the system have been specifically designed so as to be easily understood by managers and advisers whose knowledge of, and trust in, computer technology may be limited. For instance, experience has shown that managers have more confidence in their own expectations of future prices and costs than in those based on a price-forecasting mechanism. Risk and uncertainty are incorporated into model predictions only to the extent that individual managers define their price and cost expectations. Some managers prefer to include costs such as taxation or mortgage payments in their plans; others choose to ignore these costs. The choice of which costs are to be included in any computer forecast is also a matter of individual choice. This pragmatic approach appears to have been satisfactory to the British and New Zealand farmers who have used the system. However, the authors acknowledge that in situations where price and cost uncertainty are a major part of the market environment, it may be helpful to include an option to predict future prices and costs. A price-forecasting scheme for hog producers has recently been launched in Britain and the authors are watching its progress with interest (Looker).

Investigation of Management Policies

A simulation model incorporated into an information system as described above allows each user of the system to specify his enterprise in detail and to obtain a correspondingly detailed prediction of the outcomes likely to result from any given policy. Of particular interest to practising managers are the target-actual comparisons produced by the information system at regular intervals of time which

assist in overseeing the progress of their chosen plan. The need for information for adaptive management and the use of the model in budgetary control have been discussed by the authors elsewhere (Blackie and Dent). The following section illustrates the use of the model in investigating alternative management policies on hog units in Britain. Financial results from the investigations are expressed as the gross balance between income and expenditure. There has been no explicit consideration of such items as interest charges or taxation effects. Prices and costs used as data in these investigations were deterministic in accordance with the pragmatic approach outlined previously. Although it is possible to select prices and costs stochastically from an appropriate distribution and to include taxation charges, the authors believed that the following investigations would be of greater general interest if these effects were not included. The factors associated with prices, costs, and taxation are influenced highly by local conditions which would have to be explained and defined in each case. The investigations below, therefore, illustrate the use of the model as a planning aid rather than as an information system.

Bred-Gilt Production

Bred-gilt production system involves producing heavy hogs (hogs slaughtered at about 120 kg. liveweight) from gilts which have weaned their first litter of pigs. The basis of this system is the greater efficiency with which the pregnant animal converts nutrients as compared with the nonpregnant animal (English). Of crucial importance are the feasibility of conception in the gilts at an early age and at low body weights, feed conversion rates of pregnant and nonpregnant gilts, the acceptability of the bred-gilt carcass, and feed costs. Brooks and Cole and Pay and Davies suggest that the bred-gilt system is feasible. Bred-gilt production results in a 40% feed saving used per weaner produced (Brooks and Cole). Carcass acceptability of bred gilts does not appear to be a major obstacle. The average litter size in a bred-gilt herd is smaller, leading to a lower production of hogs over a given time period than would be expected from a similar sized conventional breeding herd. These data were used to examine the bred-gilt production system under three alternative policies. Policy A refers to heavy hog production from a conventional breeding herd. Policy B refers to the production of heavy hogs and bred gilts with about the same number of breeding animals as in policy A. Policy C refers to the production of heavy hogs and bred gilts from a number of breeding animals that will produce about the same number of slaughter hogs as policy A.[3]

Table 2. Data Used to Compare Bred-Gilt Systems with Conventional Heavy Hog Production

Age pigs weaned	2 weeks
Age pigs transferred to fattening house	10 weeks
Age of hogs at sale (average)	34 weeks
Liveweight of hogs at sale	118 kg
Number of pigs born per litter (bred-gilt system)	9
Number of pigs born per litter (conventional system)	10
Age of gilts at transfer to breeding house	26 weeks
Age at which gilts are bred (bred-gilt system)	29 weeks
Age at which gilts are bred (conventional system)	38 weeks
Farrowing index (litters per sow per year)	2.4
Age gilts sold for slaughter (bred-gilt system)	49 weeks

Each alternative was examined using the hog simulation model. Table 2 outlines the main assumptions. All animals sold for slaughter (heavy hogs, cull sows, and bred gilts) were assumed to be sold at $82.00.[4] This represents a price of $0.88 per kilogram deadweight for heavy hogs and bred gilts and a lower price (around $0.66 per kilogram deadweight depending on sale weight) for cull sows. Rations fed to the different groups of hogs under the bred-gilt systems were the same as those fed to the conventional unit. The bred gilts were fed as heavy hogs until they farrowed in accordance with the practice recommended by Brooks and Cole. Policy A in table 3 is comparable to policy C in terms of average annual fattening house fill.[5] A larger breeding herd, as shown by policy B, resulted

[3] The effort involved in adjusting the data to produce exact comparisons was not justified in view of the wide differences in profitability between the alternatives (see table 3).

[4] Prices expressed in this paper are in New Zealand dollars.

[5] The model can predict the percentage fill (the ratio of numbers of hogs to hog places) in the fattening house and this index may be used as a guide to the effectiveness of utilization of fattening facilities.

in considerable overcrowding in the fattening unit. Total hog sales (table 3) were significantly less in all bred-gilt systems as gilts were not available for slaughter until forty-nine weeks of age as opposed to the thirty-four weeks average slaughter age of heavy hogs. As bred gilts occupied the fattening unit until twenty-six weeks of age, there was little scope for increasing the annual throughput of hogs by increasing the size of the breeding herd. At the prices used in this set of investigations, bred-gilt production using early weaning did not appear financially viable. The saving in feed achieved using bred-gilt production did not compensate for the loss of income resulting from the reduced sales of hogs. This conclusion remained valid for the study farm when the above alternatives were examined with pigs weaned at six weeks as opposed to two weeks.

Use of Dried Poultry Manure in Hog Rations

Dried poultry manure (DPM) is currently being offered commercially as "filler" and a source of minerals in hog rations. Recent studies have indicated that at levels of up to 30% DPM, health and carcass quality were not adversely affected (Perez-Aleman et al.). However, for each 10% increment of DPM, growth rate decreased by 0.02 kilogram per day, feed conversion efficiency fell by 0.25 units and killing out percentage was reduced by 0.96. In order to assess the economic potential of this feeding practice, data were collected from a hog unit considering the use of DPM in fattening hog rations.

The unit used in this investigation comprised a breeding herd of 152 sows which sold hogs for slaughter at 89 kilograms liveweight. Three policies were considered for this unit. The first is based on the current farm feeding practice and the remaining two assume 10% and 20% DPM in the final finishing ration for hogs, respectively. The effect of DPM in the finishing diet was simulated by altering the growth rate, feed conversion, and killing out percentage parameters included in the data input to the last two policies to correspond to the research findings of Perez-Aleman et al.

The killing out percentage of hogs where DPM was not fed was 75% and the average age at slaughter of these hogs was twenty-eight weeks. Under all three policies, pigs were weaned at five weeks weighing 11 kilograms and introduced to a starter diet. Feed conver-

Table 3. Physical and Financial Parameters Using Varying Investments in Breeding Stock

System	Alternative Policy	Number of Breeding Females	Hogs Sold	Feed Use: Breeding (tons)	Feed Use: Fattening (tons)	Average Fill of Fattening House (%)	Hog Sales: Breeding ($)	Hog Sales: Fattening ($)	Feed Costs: Breeding ($)	Feed Costs: Fattening ($)	System Balance[a] ($)
Conventional heavy hog production	A	212	4,766	279	1,742	100	5,308	390,370	27,986	194,832	173,860
Bred-gilt production	B	267	4,574	358	1,704	115	40,406	338,400	34,940	197,396	146,290
Bred-gilt production	C	219	4,162	294	1,506	101	34,026	310,374	28,686	174,726	140,808

[a] System balance is balance of all costs and receipts for each system including some minor costs not shown in this table.

sion on this diet was 2.0 and hogs reached 34 kilograms five weeks after weaning and had a maximum feed intake of 1.3 kilograms of feed per day. The starter diet did not include DPM in any of the three policies. From 34 kilograms to slaughter, hogs were fed a finishing diet which contained either 0, 10%, or 20% DPM. The maximum rate of feeding for the finishing diet was 2.1 kilograms per day. Feed conversion where DPM was not included in the diet was 2.8 during this stage. Hogs under all three policies were sold at $0.32 per kilogram deadweight. At each level of DPM, i.e., 10% and 20%, three model runs were made, each with a different breeding herd size. The policy assuming no DPM was used as the basis for comparison and the model runs were grouped into three series. In series 1, each run assumed an identical breeding herd. This assumption resulted in increased pressure on fattening facilities for the two policies which included DPM in the feed since a slower throughput of hogs was involved. In series 2, the breeding herd was increased in size (for the two policies using DPM-based feed) to give a similar annual throughput of hogs as the policy which included no DPM in the feed. This resulted in even greater overcrowding in the fattening unit. In series 3, the breeding herd was decreased (for those policies where DPM was included in the feed) to keep the average annual fill of the fattening house similar to the policy which used no DPM.

Table 4 details the major physical and financial results from this investigation. In all cases, no charge was made for DPM. At zero cost, DPM could be included in the diet at the 10% level with little effect on the system balance. Most effect at this level of inclusion is evident in series 1 where the breeding herd size was identical for all policies. Twenty percent inclusion resulted in a major drop in the system balance in all cases where DPM was included in the diet. The increased feed requirement where DPM was fed (caused by the slower growth rate) more than compensated for the savings in feed costs. DPM, therefore, is unlikely to prove an economic proposition when fed under the conditions of this investigation.

Nutrient Density Investigation

A third feeding practice currently attracting research and commercial attention is the use of high-density feed. Such feed contains the same nutrients as conventional feed, but in a more concentrated form. Provided that the absolute nutrient intake per time period is not altered, hogs should exhibit similar growth patterns when fed diets of different concentrations (Filmer). Since efforts are currently being made to promote the use of high density feed, an investigation was set up to determine the break-even costs of certain high-density feeds which are offered commercially.[6] This investigation was based on a farm situation where hogs were sold at 82 kilograms liveweight with a killing out percentage of 71. Two basic policies were considered. First, the use of conventional feed for all animals in the unit was assumed. Second, the use of high-density feed for all fattening hogs was assumed, with breeding hogs and young pigs still being fed conventionally. Different growth rates of fattening hogs were also examined under the second policy to test the sensitivity of this policy to assumptions on growth rate (breeding herd size was adjusted to maintain a similar average fattening house fill at each rate

[6] Using high-density feed, Filmer and Cooke suggest the possibility of a higher rate of gain and improving killing out percentage (thus reducing feeding time to achieve the same carcass weight) at the same level of nutrient intake. This last effect is due to the reduced gut size and fill on such a diet (Filmer).

Table 4. Physical and Financial Parameters for Herds Using DPM in Fattening Hog Rations

Herd Size (sows)	Series	Dietary Inclusion Rate of DPM (%)	Total Hogs Sold	Total Fattening Feed use (tons)	Average Fill of Fattening House (%)	Income from Hogs ($)	Fattening Feed Cost[a] ($)	System Balance ($)
152	1	0	2,523	595	100	105,392	68,164	17,436
152	1	10	2,454	619	104	102,508	66,360	16,492
152	1	20	2,379	645	109	99,384	69,240	10,352
154	2	10	2,521	635	106	105,442	68,020	17,228
158	2	20	2,510	678	115	104,792	72,826	11,226
148	3	10	2,428	602	101	101,474	64,514	17,336
139	3	20	2,200	589	99	91,970	63,240	10,176

[a] DPM at zero cost.

Table 5. Feeding Regimes for Fattening Hogs

System	Ration	Maximum Feed Rate (kg/day)	Average Feed Conversion
Conventional	Starter	2.1	3.3
	Finishing	2.7	4.5
High-density	Starter	1.4	2.1
	Finishing	1.4	2.3

of growth). Under both policies, pigs were transferred to the fattening house at ten weeks at a weight of 27 kilograms and introduced to a grower diet which was either conventional or high-density. These were fed for five weeks and then a conventional or high-density finishing diet substituted. The basic feeding regime for both policies appears in table 5. Diet cost was assumed the same ($102 per ton) for both feeding methods but the rate of feeding for the high-density feed policy was restricted so as to achieve grading results comparable to conventionally fed hogs (Filmer; Filmer and Cooke). Model predictions for the various alternatives are summarized in table 6. Alternative 1 represents the results from the herd when fed a conventional diet and with most hogs achieving sale weight at twenty-six weeks of age. Alternatives 2–5 represent the same herd but with a high-density feeding regime for all fattening hogs—each alternative assuming a different growth rate in the fattening unit. The enterprise balance in this set of runs was clearly in favor of the high-density feed (table 6). As the price of high-density and conventional feed was assumed the same, it can be seen from table 6 that the difference in system balance between the two feeding practices is attributable to the savings in feed use under high-density feed regimes.

Under the conditions of this investigation, it proved economical to feed high-density feed at a cost of up to 110% above conventional feed if two weeks saving in time of slaughter was possible. This may well prove feasible if the improvements in growth rate and killing out percentage mentioned previously can be achieved in commercial practice. Where hogs fed high-density feed reached slaughter at the same age as conventionally fed hogs, a 62% premium was the maximum justified for high-density feed and this fell to 38% if high-density feeding resulted in an average age at slaughter of twenty-eight weeks. These results suggest that high-density feed could prove of economic benefit to the individual farm manager.

Conclusions

Simulation models have a considerable potential for use in assisting managers in investigating alternative management policies. However, as yet this potential has not been fully realized largely due to the nature of the models built. This paper has discussed the use of a hog simulation model in an investigationary mode and has illustrated this use in relation to possible management strategies for individual herds. The alternatives discussed in this paper show clearly the wide gap between promising research and its application at the farm level. Both the bred-gilt system and the use of DPM in hog feed offer significant potential savings in feed cost. However, the nature of the herds on which these methods of production were tested were such that feed cost savings were more than offset by a slower throughput of hogs. The ultrahigh-density feed investigation showed the sensitivity of this production method to changes in growth rate. A model of the sort described here may ease the communication problem between researchers and practitioners by providing a common medium on which research results may be evaluated for individual circumstances.

The hog simulation model and the accompanying information system are attempts to allow farmers access to the power of a compu-

Table 6. Physical and Financial Parameters for a Hog Unit

Alternative Policy Number	Feeding Regime	Number of Sows	Average Fill of Fattening House (%)	Fattening Feed Used (tons)	Number of Hogs Sold	Average Age at Slaughter (weeks)	Income from Hogs ($)	Expenditure on Feed: Breeding ($)	Expenditure on Feed: Feeding ($)	System Balance ($)
1	Conventional	133	103	484	2,269	26	84,252	29,372	50,142	3,998
2	High-density	133	102	330	2,191	26	88,256	27,468	34,270	25,776
3	High-density	134	100	321	2,330	25	93,820	29,524	33,182	30,324
4	High-density	144	100	316	2,520	24	101,554	31,670	32,380	36,636
5	High-density	114	104	347	1,974	28	79,730	25,482	36,088	17,468

ter in a way which is easy to use and which produces meaningful results. It is intended, in the near future, to incorporate a feed formulation service into the information system. This facility will be of major benefit in the New Zealand situation where most hog producers mill and mix their own feed. Other additions, such as price forecasting mechanism, could be appended to the model with little difficulty in order to make the model more useful in particular local circumstances. The main direction of ongoing work on the hog information system is in developing the system from a pilot scheme into a fully operational management service in cooperation with the New Zealand Pork Industry Council. (Readers interested in using the system should write to Malcolm Blackie.) The methodology developed for the hog simulation model is also being used to develop similar models for other farm enterprises.

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Economic Impact of Restricting Feed Additives in Livestock and Poultry Production

Thomas Mann and Arnold Paulsen

Effects of feed additive restrictions on meat production have been measured in previous studies. An econometric simulation model is used in this study to evaluate the impact of policy alternatives on costs, prices, and net profits in beef, pork, broiler, and turkey production over a ten-year period. Under the model, all the restrictive policy alternatives produced wholesale price increases. Simulation estimates of price and production cost increases, however, were lower than previous findings. Health risk reductions may be obtainable at a smaller loss in economic efficiency than previously suggested.

Key words: economic efficiency, feed additives, health risk, simulation.

The restriction or elimination of feed additives in livestock and poultry production has become a significant public policy question as a result of concerns voiced about potential public health hazards associated with such additives. Federal regulations have been established primarily to guard consumers from allergic or toxic reactions to meat products containing additive residues. A second potential hazard, which has been identified more recently, is that continued subtherapeutic applications of antibiotic additives may produce bacteria immune to classes of antibiotics. Any development that would make humans more susceptible to disease necessitates a reevaluation of a technology, despite its proven profitability.

Policymakers are attempting to meaningfully relate health risk reductions to changes in economic efficiency to accurately predict the impact of regulatory restrictions on production. Restricted use of feed additives could reduce productivity of animal feed and might cause significant changes in swine and poultry housing methods. In addition, the quantity of meat marketed would probably decline and retail prices rise. To make accurate predictions, it is necessary to establish valid measures of health risks and their effects on economic efficiency.

This paper uses one technique to estimate the costs of a restrictive policy in terms of expenditures and consumption for meat. Quantitative estimates of returns to producers and costs to consumers over time are provided, and the distribution of these impacts among producing and consuming groups is described. We have used an econometric model to simulate the livestock and poultry industries. The recursive model consists of forty-two sequential linear equations to approximate production and marketing relationships of live animals and meat in the United States and is fitted by least squares with quarterly data from the period from 1962 through 1972.

Feed activities analyzed include subtherapeutic chemical and biological additives to livestock and poultry feed which stimulate growth, increase feed efficiency, and reduce mortality. These include growth hormones such as Diethylstilbestrol (DES) and Melengesterol Acetate (MGA), as well as antibiotics. Antibiotics include the true antibiotics (tetracyclines and penicillin) and the synthetic antibiotics (sulphonamides, nitrofurans, and arsenicals), all of which inhibit subclinical infection and microbial growth in the digestive tract and circulatory system.

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Previous Research

Previous studies analyzed the economic impact of eliminating the use of DES and antibiotics. All previous studies, however, used a comparative statics analysis: comparing the equilibrium of a preban period with the equilibrium of a postban period. Such studies determined the impact of the ban on equilibrium farm prices, retail prices, and per capita consumption. Studies by Paulsen and Butz analyzed the impact of restricted use of antibiotics in swine production. A U.S. Department of Agriculture study (1971) analyzed the impact of eliminating DES. This research also analyzed the welfare impacts of higher feed grain usage. Another USDA study (1972b) also published in Gilliam et al. considered the economic impact of banning subtherapeutic use of antibiotics in broiler and turkey production.

The comparative statics studies did not trace out the time path of adjustment. For example, the USDA study (1971) postulated two possible producer responses to a ban on DES. In the first case, the same number of animals would be fed for a longer period of time and marketed at the same weights as in the preban period. Producers would simply use more feed over a longer time period for the same number of animals to achieve the same total output, which would sell at the same price as before. In the second case, cattle numbers were held constant, but the animals were marketed at lower weights. A comparative statics framework permits the analysis of both types of situations since two equilibriums of the same time length can be compared.

If cattle on feed at the time of the DES ban actually experience a lower than normal rate of daily gain, the market will certainly be presented with a smaller total tonnage of beef in every time period. It is possible that the number of steers on feed will increase in response to higher prices, but a smaller tonnage of beef must be accepted per month in the transitional period. Slowing the rate of gain would cause a onetime reduction in beef production and raise prices just as speeding up the rate of gain by the adoption of DES caused a onetime increase in production and reduced prices. DES adoption, however, occurred over several years, and the effect was less discernible. The complete elimination of both DES and antibiotics at the same time (during the transition period) would reduce output each quarter below the level existing before the ban and below the eventual equilibrium level.

Method

The simulation model improves upon the comparative statics approach by accounting for, and estimating the impact of, withdrawal of feed additives on feed productivity or feed efficiency. Reduced feed efficiency will raise producer costs and reduce feed-to-meat conversion ratios. Reduced feed efficiency can be expected to reduce feeding rates per head per day and cause a search for other factors to substitute for feed at the margins if possible. Reduced feed efficiency results from reduced daily rate of gain. This raises the proportion of feed used for basic metabolism or maintenance and thus raises feed costs per unit of gain and lowers supply of grain-derived meat at any given price relationship between meat and grain.

The USDA (1972a) report on DES and antibiotics used expert judgment and pharmaceutical industry estimates of rate of adoption of feed additives. This study in contrast uses the results of two sample surveys of adoption rates done in Iowa. The USDA assumed antibiotic usage was 80% of all steer and heifer cattle marketed in 1970 and 90% of all growing pigs. Hutton in 1971 estimated that 34% of cattle on feed and about 85% of hogs on feed were being fed antibiotics. In a 1972 survey of Iowa swine producers, James and Beneke reported that 84% of growing pigs were fed rations including an antibiotic. For the purposes of this study, the authors relied upon the Hutton study and assumed that 31% of steers and heifers marketed and 75% of all barrows and gilts marketed were fed antibiotics.[1]

The simulation model used covers the United States and includes beef, hogs, lamb, broilers, and turkeys. It was constructed by Rahn and modified by Mann et al. It can estimate the impact of feed additive prohibitions by simulating the meat animal markets with and without feed additives. Prices, per capita consumption, resource returns in livestock

[1] It cannot be proven at this time that projections based on Iowa samples are more accurate than the USDA assumptions. However, we view the surveys as the best available evidence. The use of lower adoption rates does reduce the consequences of removing feed additives. Estimates on rate of adoption from the Iowa surveys are presented in Mann as well as estimates on average rate of gain, feed efficiency, and mortality.

production, and total costs to the consumer can be compared between the simulations with and without feed additives. The simulation presents estimates for each quarter during the transition period.

To simulate the ban of feed additives, the biological or physical relationships in the model were adjusted, but the market relationships were held constant. The biological impact of banning feed additives was simulated through appropriate adjustment of selected physical coefficients. Three biological responses were explicitly acknowledged for each livestock and poultry class: first, lower daily rate of gain; second, increased feed and other input requirements per unit of meat; third, higher mortality and lower reproduction rates. Stock-to-slaughter coefficients and reproduction variables like pigs saved per litter were reduced to reflect increased livestock and poultry mortality.

For antibiotics, three series of adjustments were entered in the model for each animal class. First, the immediate impact of the change in rate of gain on livestock numbers coming to market was indicated by shifting a percentage of animals for slaughter from one quarter to the succeeding quarter. The percentage was calculated as the estimated rate of adoption multiplied by the estimated improvement in rate of gain due to antibiotics.

We believe that the absolute values of most variables in our quarterly simulation model are relatively credible within six to eight quarters, but beyond that range particular values quickly acquire a wide confidence interval. Short-term estimates are based on more accurate forecasts of exogenous variables. Nevertheless, the model's alternative long-run simulations still serve long-term analysis by estimating deviations from the benchmark, that is, they indicate change in trends in livestock associated with banning feed additives.

To illustrate, a detailed examination of the adjustment for hogs is presented. In the Mann et al. simulation, the barrow and gilt slaughter equation is

$$(1)\quad HBGQ\,(I) = -5910.8 + 338.8D4 + 2886.1D3 + 4031.1D2 + 39.67\$HP(I\text{-}1) + 5.246\ HPI(I\text{-}2) + 0.6243\ HSFQ(I\text{-}2)\cdot HPSL(I\text{-}2) + 0.3984\ HSFQ(I\text{-}3)HPSL(I\text{-}3).$$

(For definition of variable refer to table 1.) The hog profitability index is

$$(2)\quad HPI(I) = HP(I) - HTC(I).$$

Equation (1) estimated that in the preban period approximately 62% of the barrow and gilt slaughter in current quarter I comes from the pig crop ($HSFQ \cdot HPSL$) in quarter I-2, and 39% from the pig crop in quarter I-3. This is an average biological rate of maturation which was adjusted downward as a result of banning feed additives.

To reflect the effect of the antibiotics ban in reducing rate of gain, numbers of hogs marketed for slaughter were reduced and delayed. The coefficients relating the pig crop ($HSFQ \cdot HPSL$) to hogs sold ($HBGQ$) were adjusted. Because aggregate rate of gain was reduced by 9.025% (75% rate of adoption times 10.7% decrease in rate of gain), this implied that 8.025% fewer butcher hogs would be coming from the I-2 pig crop and 8.025% more barrows and gilts would be coming from the I-3 pig crop. Hence, the new equation for barrow and gilt slaughter is

$$(3)\quad HBGQ(I) = K + 0.5742\ HSFQ(I\text{-}2)\cdot HPSL(I\text{-}2) + 0.4304\ HSFQ(I\text{-}3)\cdot HPSL(I\text{-}3),$$

Table 1. Variables in the Equations

Variable Notations	Variable Identification
HBGQ	Barrow and gilt slaughter (1,000 head)
HSFQ	Sow farrowings (1,000 head)
HPSL	Pigs saved per litter
HP	Hog price ($/cwt.)
$HP	Change in hog price ($)
HPI	Hog profitability index ($/cwt.)
I, I-1, I-2, etc.	Quarter: I = current, I-1 = last quarter, etc.
D2, *D3*, *D4*	Seasonal variables to adjust the intercept constant for second, third, and fourth quarters
SBMP	Soybean meal price, 44%, Decatur ($/ton)
FLW	Farm laborer's wage (excludes room and board)
HTC	Hog total cost ($/cwt.)
CP	Corn price, #3 yellow, Chicago ($/bu.)

where K equals all the other variables in the original equation.

The second adjustment indicated the impact of changes in feed efficiency and rate of gain on production costs. Because rate of gain was reduced by 8.025%, feed efficiency is reduced by 3.825%, according to Mann. Reduced feed efficiency raised producer costs through the hog total cost variable in the hog profitability index. The feed requirement of hog total cost was increased by 3.825% to reflect the aggregate impact of decreased feed efficiency. Labor requirements were increased by 8.025% on a per hundredweight basis because more labor is needed when it takes longer to produce 100 pounds of pork. Fixed capital or overhead requirements per hundredweight were increased by 8.025% because less pork would be forthcoming from the same physical facilities per year but with the same operating costs. The old and new hog total cost functions, which are on a per hundredweight basis, are

(4) $HTC(\text{I}) = (1.559\ CP(\text{I}) + 0.0075\ SBMP(\text{I}))\ 6.05 + 1.27\ FLW(\text{I}) + 3.0,$

and

(5) $HTC(\text{I}) = (1.559\ CP(L) + 0.0075\ SBMP(\text{I}))\ 6.28 + 1.37\ FLW(\text{I}) + 3.25.$

Thus, the adjustment of the biological variables of the model affected not only immediate barrow and gilt slaughter, but also the hog profitability index, which in turn affected sow farrowings, sow slaughter, and average slaughter weight in future periods.

The removal of antibiotics would probably increase mortality of pigs and thus reduce pork marketings in the third and fourth quarters after the ban and permanently reduce sow herd efficiency. More pigs, especially baby pigs, would die without the prophylactic protection of antibiotic feed additives. This increase in mortality was estimated to be similar to the decrease in mortality associated with the adoption of antibiotic feed additives in the early 1950s. Paulsen and Mann report the results of a regression analysis of national and Illinois pigs saved per litter since 1930. The best fit was obtained by a linear regression shifted upward about one-third pig per litter in 1953. Thus, the exogenous variable pigs saved per litter (*HPSL*) in the barrow and gilt slaughter (*HBGQ*) equation of the simulation was adjusted downward by one-third pig per litter for sows farrowing after the ban of antibiotics.

The combined result of all the adjustments made in the simulation was a reduction in number of hogs marketed and a reduction of resource efficiency in pork production. Similar procedures were used in the beef, broiler, and turkey sectors to adjust historical, biological, and cost coefficients for the removal of feed additives. (Adjustments are presented in Mann, tables 5-4 through 5-8.)

The model generated quarterly values of the endogenous variables for each of four simulations. For the purposes of this presentation, the following variables are discussed: (*a*) beef, pork, broiler, and turkey wholesale prices (quarterly), (*b*) cattle feeder and hog producer net profits (quarterly), and (*c*) total consumer expenditures at wholesale level (yearly).

Results

Simulation One: Benchmark

The endogenous variables in live animal and meat markets are simulated from the first quarter of 1973 through the fourth quarter of 1979 assuming continued use of feed additives. The demand and supply equations reflect average relationships of 1962–72. The level of income and population for the future reflect continued growth. Feed prices were returned by 1977 to $1.75 per bushel of corn, just above 1972 levels.

Simulation Two: Banning Antibiotics

Only antibiotics would be restricted as animal feed additives in poultry feeds and in hog and cattle feeds as of July 1, 1973. The possibility of a residual effect after the effective dates exists. Therefore, reduction in feed efficiency, rate of gain, and increased mortality on poultry were assumed to begin the second quarter of 1973 and to begin affecting hogs and cattle in the fourth quarter of 1973. The pattern of production tended immediately downward. Upward change in wholesale prices from the first quarter of 1973 through the fourth quarter of 1977 are given in table 2.

The major effect of the antibiotics restriction was felt in the pork production sector. Wholesale pork prices began to rise three months after the ban in late 1973, peaking at a price increase of $3.91 per hundredweight in the first quarter of 1975. This increase was 4.5% greater than the simulated wholesale price with antibiotics for the same quarter.

Table 2. Difference in Wholesale Prices from Benchmark Simulation

	Simulation 2: Banning Antibiotics				Simulation 3: Banning DES				Simulation 4: Using Replacement Technology			
Year and Quarter	Beef	Pork ($/cwt.)	Broiler	Turkey	Beef	Pork ($/cwt.)	Broiler	Turkey	Beef	Pork ($/cwt.)	Broiler	Turkey
1973-1	0	0	0	0	0.30	0.02	0.02	0.01	0	0	0	0
-2	0	0	0	0	0.36	0.03	0.03	0.03	0	0	0	0
-3	0	0	0.06	0.61	1.02	0.08	0.08	0.08	0	0	0.06	0.61
-4	0.01	−0.02	0.13	0.21	2.10	0.16	0.16	0.03	0.93	0.05	0.14	0.23
1974-1	0.02	−0.01	0.04	0.11	3.33	0.27	0.26	0.05	0.94	0.06	0.11	0.11
-2	0.45	1.81	0.37	0.52	3.80	0.29	0.29	0.01	1.38	1.96	0.44	0.51
-3	0.50	3.01	0.65	1.41	4.29	0.45	0.36	0.03	1.59	3.09	0.73	1.41
-4	0.58	3.62	0.72	1.14	4.57	0.46	0.37	0.03	1.69	3.82	0.83	1.17
1975-1	0.66	3.91	0.77	1.08	4.63	0.40	0.36	−0.01	1.58	4.18	0.87	1.12
-2	0.57	3.56	0.70	0.86	4.69	0.57	0.39	0.03	1.27	3.27	0.68	0.73
-3	0.27	2.31	0.52	1.25	4.86	0.95	0.47	0.13	0.62	1.33	0.31	1.01
-4	0.32	1.65	0.35	0.69	4.38	1.08	0.47	0.17	0.45	−0.47	−0.07	0.20
1976-1	0.40	1.47	0.33	0.51	4.47	1.13	0.48	0.19	0.22	−2.00	−0.34	−0.31
-2	0.31	0.97	0.23	0.23	4.57	1.35	0.54	0.24	−0.06	−2.66	−0.46	−0.68
-3	0.07	−0.08	0.11	0.71	4.59	1.65	0.60	0.30	−0.09	−2.94	−0.42	0.01
-4	−0.01	0.12	0.08	0.31	3.02	1.45	0.47	0.24	−0.43	−2.72	−0.45	−0.38
1977-1	0.03	0.80	0.20	0.34	2.75	1.26	0.41	0.23	−0.50	−1.89	−0.33	−0.30
-2	−0.11	0.62	0.17	0.22	2.69	1.34	0.43	0.29	−0.37	−0.72	−0.11	−0.13
-3	−0.37	−0.18	0.06	0.63	2.30	1.43	0.41	0.29	−0.49	−0.01	−0.06	0.65
-4	0.01	0.43	0.14	0.39	2.26	0.99	0.34	0.19	−0.22	0.47	−0.10	0.32

Farm level hog prices rose more than $2.00 per hundredweight in the same period, and net profits to pork producers rose $4.42 per head, or 4.5%, over the benchmark.

Although many pork producers have resisted the feed additives ban, simulation analysis indicates that the simultaneous withdrawal of feed additive technology from all pork producers would not lead to financial disaster for the average hog producer. Individual and total production would decline, but prices would increase more than proportionately, at least temporarily, pushing average profit of hog production up after the ban.

The estimated price of broilers and beef would also rise as a result of an antibiotics ban and could peak in the first quarter of 1975. At this point, the wholesale beef price was $0.66 per hundredweight (or 1.1%) above the benchmark; the wholesale broiler price was $0.77 per hundredweight (or 2.2%) above the benchmark. The turkey sector peaked in the third quarter of 1975 when the wholesale turkey price was $1.25 per hundredweight (or 3.4%) above the benchmark.

At the wholesale level in the postban simulation, total consumer expenditures for meat are estimated to increase $500 million over the simulation with antibiotics for the same seven-year period.

After three years of the antibiotics ban, higher farm and wholesale prices for livestock and poultry stimulated increased supplies, which, in turn, narrowed price differentials and reduced returns per head to about normal preban levels. The long-run effect of the antibiotics ban for hogs is higher consumer cost but little change in pork producer profitability.

Simulation Three: Banning DES

Because DES is used only with steers to simulate the market effect of its ban, adjustment of model coefficients was required only in the beef sector. The resulting wholesale meat price differentials are presented in table 2. The impact on the beef sector was significant and continuous. Price increases for wholesale beef peaked in 1975 at $4.86 per hundredweight (or 7.4%) over the benchmark. The impact of banning DES also spread to pork, broiler, and turkey wholesale prices. The peak effect on these related meats occurred a year later in 1976. Another major impact of the DES ban is first to increase and then to reduce the average cattle feeder's net profit. Estimates of net profit per head were increased up to $3 per head in the first year, then permanently reduced by the DES ban throughout the rest of the simulation by $3 to $10 per head.

Because beef supplies decline and wholesale and retail prices increase while producer net returns fall after the first year, it seems that reductions in the rate of gain and feed efficiency resulting from the DES ban would adversely affect most everyone. Net profits to cattle feeders would be reduced because the simulation estimates that cattle feeders would be unable to pass increased costs on to consumers as they did in the case of the antibiotics ban. Consumer expenditures for beef would rise $2,356 million over the five-year, postban, simulation period.

Simulation Four: Banning Antibiotics and DES with Replacement Technology

This simulation acknowledged the possibilities of replacement technology. Antibiotic replacement technology exists or is within a year or so of perfection. It consists of adopting compounds of tylosin and bacitracin in place of compounds containing tetracyclines, penicillin, and sulfonamides. Technological replacements for DES currently consist of the implants Synovex and Ralgro for steers, and Synovex and MGA for heifers. Even if Synovex is eventually found to contain a carcinogenic estrogen and banned, two other alternatives now exist and others may be developed.

Replacement technology simulation forces the analyst to address several questions. How quickly will this technology be available and adopted? Will the technological alternative be equally effective? Will enough replacement compounds be available at prices equivalent to those of original compounds to insure rapid adoption of the substitute? Will successful adoption of new compounds involve any changes in facilities or management that would keep adoption levels of the replacements below those of the previously banned compounds? A perfect substitute will probably not be found. Replacement technology, however, was assumed to be equivalent to original technology in all the areas mentioned. Replacement technology was assumed available one year after the ban of the unacceptable compound and gradually adopted over the second year to the effective level of the original technology.

Wholesale prices greater than their benchmark levels are simulated during the ban. A

year after the replacement technology has been completely adopted, however, wholesale prices of both the beef and pork have dropped below the benchmark projections. The stimulation to supply, provided by increased prices during the ban, produced lower prices later when combined with replacement technology. Total consumer expenditures during the simulation would be expected to increase over the benchmark.

Conclusions

Simulation seems to be a valuable tool for environmental impact analysis. The accuracy of this particular simulation cannot be conclusively established here. It does seem to depict the theoretically expected pattern of impact and adjustment over time.

The major impact of banning antibiotics in 1973 would have been a permanent increase in prices and a temporary increase in producer net return simulated to take effect in five to seven quarters. The same pattern would be expected in removal of any technology, but exact degree and time lag would be unique to each technology and economic sector.

The contribution of technology is determined by both biological and behavioral response patterns. The presence of cross-price elasticities of demand between pork and other meats allowed the effect of reduced production in pork to be spread over the larger meat sector. The output reduction in the pork sector was only slowly and partly offset by expansion in poultry production.

In the Gilliam et al. study of antibiotics restrictions, total annual consumer expenditures for beef, veal, and pork would increase more than $1.6 billion. This simulation estimates about $500 million over five years. In the USDA study (1971) of DES restrictions on beef, per capita consumption declined 3.7% (carcass weight) and retail beef prices increased about 3.6%, for a total annual expenditure increase of $458 million. In this simulation, consumption decreased by 2% to 3.25%, wholesale prices rose 4% to 6%, and consumer expenditures rose $2.3 billion in five years.

The trade-off between public health and food production costs remains to be evaluated for public policymakers. This study attempts to structure the policy trade-off. Quantified estimates of the improvement in health from banning antibiotics and DES are urgently needed. The banning of antibiotics and DES is certainly not final nor is it the last of this type of policy decision to be made. Society faces a continual challenge to accurately weigh environmental risks and economic efficiency. Analytical tools will have to be appropriate and accurate if intelligent, collective decisions are to be made. Well-formulated simulation is one tool that can improve the decision-making process.

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The Value of Information and the Value of Theoretical Models in Crop Response Research

Richard K. Perrin

The concepts of the value of information and the value of alternative models are developed and applied to corn response research in Brazil. Soil test information was worth as much as $30 per hectare and the response model employed was worth up to $23 per hectare, but two soil classification models had negative values.

Key words: fertilizer response, soil testing, value information.

When production functions first began to be applied to the economic analysis of crop response to fertilizer, the primary methodological problem seemed to be the choice of the algebraic form of the function. But soon, other troublesome questions appeared. How should the profit-maximizing principle be altered in recognition of farmers' risk aversion? Data from different experiments, or even from the same experiment in two different years, often gave rise to quite different optima. How are these results to be reconciled? Should the data from different sites and different years be combined? And since each additional experiment gives yet another optimum, how long should one keep on experimenting? Furthermore, most farmer recommendations are based on the soil's classification and on soil test results—how can these factors be systematically incorporated into the response-analysis approach?

These and other questions related to the economics of crop response research and fertilizer recommendation procedures are quite important in view of the considerable sums of money expended around the world in conducting response experiments, in testing soils, and in making recommendations to farmers. The thesis of his paper is that these questions can be best understood within the context of the economics of information. Two concepts, the value of information and the value of alternative models, are described. The concepts are then used to examine the value of two alternative production function models and three soil classification schemes and the value of soil test information in the analysis of corn response data from Brazil.

The Economics of Information Applied to Response Research

The type of research at issue here is applied response research, the results of which are intended to be of direct use to persons who must make production decisions.[1] In order to establish a framework for evaluating such research, we must begin with the decision maker and the decision which is at issue. The decision variable of interest here is the level of fertilizer to be applied to a crop, designated as the vector F. The outcome, or payoff, from the decision is the net return to fertilizer use, defined as the value of the crop obtained minus the cost of the fertilizer.

The payoff is related to the decision through some imperfectly understood and imperfectly controlled production process. The arguments of the production process include not only F but a host of other variables, only some of

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[1] Much agronomic research is also, or perhaps exclusively, more basic in nature, designed to reveal a greater understanding of the production mechanism, with little or no direct relevance to the farm decision-making process. Such research must be evaluated on some basis other than that developed here.

which can be controlled or even identified. This imperfectly understood production process can be approximated by some theoretical model, or production function, such as

(1) $$Y = g(F, C, T, W, e),$$

where Y is crop yield, C represents site characteristics as embodied in a classification of the soil by some taxonomic system, T represents site characteristics as measured by soil tests, W represents weather or any other factors of production which can be measured but not controlled or predicted, and e is a residual term representing the effects of other unidentified factors in the production process.[2]

Each of the arguments of equation (1) can be interpreted either as vectors or as scalars. The payoff is related (approximately) to the decision variable as

(2) $$\Pi = p\, g(F, C, T, W, e) - PF,$$

where p is the value of additional units of yield and P is the price of fertilizer. Since the random variables W and e cannot be observed prior to the decision, the payoff itself is a random variable for any given level of fertilizer, F.

This representation of the decision problem is not particularly novel, but it emphasizes an aspect of the problem that is too often ignored in fertilizer response research. This is the fact that the production process is contingent upon the characteristics of the individual site, as well as upon weather and fertilizer application. Since the soil classification and soil test variables vary from site to site, the optimum F also varies from site to site.[3] The decision maker must make fertilizer decisions for a whole population of sites, and this is true whether the decision maker is an individual farmer or a remote decision maker making recommendations to farmers.

Consider now the implications of the above conceptualization for a decision maker who begins with very little information about the optimum fertilizer levels, F, for his population of soils. The decision maker can search for information about the relationship between his decision variable, F, and his payoff. He can search for a number of kinds of information in various amounts, presumably guided by the principle that information should be acquired as long as its value exceeds the cost of obtaining it. The decision theory advanced by Schlaifer and used by a number of agricultural economists provides a framework for estimating the economic value of any particular piece of information. To paraphrase Schlaifer, the value of a bit of information is the difference between the decision maker's current expectations of (a) the payoff value that will result if he chooses his act as well as he can without obtaining the information, and (b) the payoff value that will result if he were to obtain the information and then choose his act as well as he can. In other words, the value of the information is the increment in expected payoff that can be realized by utilizing the information in making the decision.

In choosing a fertilizer level, accepted theory implies that expected utility, rather than expected dollar payoff, provides the criterion for choosing among alternative fertilizer levels. As a first approximation, however, the value of information can be described as the increment in expected dollar payoff which can be realized by utilizing the information. If the expected dollar value of the information is small relative to the decision maker's total wealth or if the decision maker is risk-indifferent, the criterion of maximum expected dollar payoff is equivalent to the criterion of maximum expected utility. Furthermore, the money equivalent of the increment in expected utility must be smaller than the increment in expected payoff, at least for risk averters. Expected payoff thus provides an upper bound estimate of the value of information.

The first step in searching for information is to draw a sample of production sites and obtain from them some observations on the production process represented by equation (1). With respect to this stage of research, two important questions have been explored in the literature. First is the question of the optimum sample size, i.e., the number of experiments to conduct either in a given year or through time. This question has been explored by Anderson and Dillon, and while it is a significant question, it will not be addressed in this paper.

[2] Statistically, this specification of the production process is not and cannot be a very happy one. We do not know and can never know the "true" specification of the process. If such a thing exists at all, we will misspecify it by omitting variables, choosing the wrong algebraic form, and measuring the variables inaccurately. We should therefore be more concerned with testing the hypothesis that this theory predicts better than the next best alternative, rather than the hypotheses that the coefficients of some particular algebraic specification equal zero.

[3] This is true for either an *ex post* optimum (after weather and other time-dependent variables can be observed) or an *ex ante* optimum (before these variables can be observed). But we will be concerned here with the *ex ante* optimum, since it is the only one relevant to this particular decision process.

The Value of Alternative Response Models

A second question which has received a great deal of attention is the appropriate choice of a model (variables and algebraic form) to specify the response function (1) for estimation. Most of the literature dealing with this choice has dealt with statistical criteria for making the choice among response models, but two studies (Havlicek and Seagraves, Anderson) have raised the question of the economic value of alternative models. Extending Schlaifer's logic, the economic value of a production model can be defined as the difference between the decision maker's current expectations of the payoff value that will result if he chooses his act using the production model in question and if he chooses his act using the next best production model available. In other words, the value of a response model is the increment in expected payoff that can be realized by using that model rather than the best alternative model in making a decision.

Both of the studies just cited calculated the economic value of a production model under the very restrictive assumption that the response model in question, as estimated, is the underlying production model. Since it is impossible for us to ever know the true model, a more realistic (though more expensive) method of determining the value of a model is to draw new samples (experiments) from the production population to obtain an estimate of the difference in expected payoff between the decisions based on the model in question and those based on the alternative model.

The Value of Soil Test and Soil Classification Information

Once the decision maker has collected data and estimated the production function (1), he must decide how much information to obtain about each site prior to making the fertilizer decision for that site. One aspect of this problem is the simple question whether he should determine the soil class, C, and/or obtain a soil test, T, for each site for which he must make a decision, that is, should a uniform amount be applied to all sites, or should the amount be tailored to each site? Furthermore, additional information may be obtained about probable values of the weather variables, W, for the current season. In each of these instances, there will be a cost to obtaining the information, which must be weighed against the value of the information. The value of any one bit of information can be defined as before, i.e., the increment in expected payoff which can be realized by utilizing the information.

The problem of assessing the value of soil test information has been addressed by Ryan and Perrin and by Colwell. The problem of assessing the value of weather information has been addressed by Byerlee and Anderson and by Doll. The value of soil classification information has been studied by Bie and Ulph and by Batavia. The procedure in the past has been to assume that separate response functions should be fitted for each soil class. But, given the production process specified in equation (1), soil class is but another variable in the production function. The question of whether to group sites into similar soil classes is identical to the question of whether to obtain information about the soil class, the variable C. In deciding whether to identify a soil before making a decision, one needs to ask whether the value of this information exceeds the costs of obtaining it.

There is yet another aspect of the site-information search problem. Just as there are alternative theoretical production models, there are also alternative soil classification models, alternative soil testing techniques, and alternative weather measurement models. As is the case for production models, each of these latter models must be considered as nothing more than approximations of reality, and the appropriate method of choosing among them is to calculate and compare their economic values. The value of a soil classification model, for example, will be the increment in expected payoff which can be realized by using that model rather than an alternative classification model. The alternative, of course, might be no classification model at all—pooling all sites together regardless of soil class.

In this section of the paper, two areas of application of the value of information are suggested, the question of the optimum number of experiments to conduct and the question of the amount of information to obtain about each site for which a decision must be made (soil classification, soil test, weather, etc.). Two areas of application of the value of a model are also suggested, the question of which response function model should be employed, and the question of which soil classification model (if any) should be employed.

Application to Corn Response in Brazil

The first question is which of two response models should be used, a generalized quadratic model or a "linear response and plateau" model as proposed by Waugh, Cate, and Nelson. The second question is related to the value of soil test information, and third the question is the value of two very simple soil classification schemes. The data used are from sixty-one experiments on the fertilizer response of corn conducted in the state of Minas Gerais from 1967 to 1969. (These data were gathered together by Robert Cate and the Brazilian Ministry of Agriculture.)

Procedures

Of the two response models, agricultural economists are familiar with the generalized quadratic response model. Yield is expressed as a quadratic function of fertilizer inputs and soil test. Interaction terms between these allow for differences in fertilizer response by soil test levels.

The linear response and plateau model (LRP) postulates a response curve exactly as the name implies. For any given nutrient, the nonfertilized yield is termed the threshold yield. As the level of this nutrient is increased, yield is assumed to increase from the threshold yield at a constant slope until a plateau is reached, at which time no further increases in yield can be obtained by additional doses of the nutrient. Of course, the level of the threshold yield, the slope of the response, and the height of the plateau will depend on the level of other nutrients applied. But the agronomists who proposed the model intended that the LRP for any one nutrient be estimated under conditions of a nonlimiting supply of the other major nutrients.

The LRP model is somewhat alien to agricultural economists, who tend to think of the world as having smooth curves rather than corners. On the other hand, it provides an approximation of a phenomenon that many agricultural economists have noted—that response curves often tend to be quite flat on top. The model allows only two rational levels of fertilizer, none at all or the amount required to reach the plateau (the nutrient "requirement"), depending on the price ratio and the slope of the linear response.

The LRP model has two potential virtues. First, it will likely result in lower fertilizer recommendations than curvilinear models applied to the same data. This is a virtue because experience has shown that curvilinear models generally result in recommendations higher than farmers are willing to undertake, presumably because of uncertainty and risk aversion. The second potential virtue is that it is very easily estimated by simple graphic methods. This can be an important consideration, given scarcity of statistical expertise, economic expertise, and computer facilities. Of course, the potential drawback of the model is that its inflexibility may result in serious specification error in estimating fertilizer response. If so, this should be detected when the value of this model is compared to that of the generalized quadratic model.

The formal classification of the soils on the sixty-one experimental sites was unknown at the time of this study, but several Brazilian soil scientists suggested that more homogeneous groupings of the sites would be helpful. As one alternative, they suggested grouping separately those sites with soil phosphorus in excess of ten parts per million from those with less. As a second alternative, they noted that the tests were conducted in two geographical regions of the state by different research groups. Geographical area, therefore, provided the second classification model. While these two simple approaches may not seem worthy of the title of soil classification models, they nonetheless serve the same purpose.

The procedures used to evaluate the response models, the classification models, and the soil test information, are as follows. Of the sixty-one experiments, thirty-one were randomly selected to provide data for the estimation of the response models. The remaining experiments were set aside to provide data for estimating the value of the models and soil test information. Five of the experiments in the estimation subset and two in the evaluation subset had incomplete soil test information, leaving twenty-six experiments for estimating the response models, and twenty-eight for evaluation.

Prices used in the analysis are \$0.045 per kilo of corn, \$0.30 per kilo of N, \$0.34 per kilo of P_2O_5 and \$0.14 per kilo of K_2O. These are the approximate prices prevailing in the area in late 1973.

A conceptual problem arises from the use of the data in this manner. Using the evaluation subset of the data, we wish to compare the

Table 1. Quadratic Response Function for a Subset of Minas Gerais Corn Experiments

Variable Description	Units	Average Value	Estimated Coefficient	(t-ratio)
Intercept [a]	kg/ha	—	23,302	
Applied N, (NA)	kg/ha	74.67	− 11.52	(−0.85)
Applied P_2O_5, (PA)	kg/ha	68.62	48.49	(3.48)
Applied K_2O, (KA)	kg/ha	33.49	− 1.12	(−0.10)
Soil P, (PS)	ppm	13.24	6.67	(0.18)
Soil K, (KS)	ppm	85.68	73.39	(6.56)
pH, (PH)	standard	5.28	−8518.18	(−1.51)
$(NA)^2$			− 0.0181	(−2.90)
$(PA)^2$			− 0.0869	(−3.17)
$(KA)^2$			0.0042	(0.03)
$(PS)^2$			0.0460	(0.12)
$(KS)^2$			− 0.1953	(−3.64)
$(pH)^2$			721.5745	(1.36)
(NA) (PA)			− 0.0023	(−0.12)
(NA) (KA)			− 0.0139	(−0.33)
(PA) (KA)			0.0794	(1.83)
(NA) (PH)			4.3470	(1.75)
(PA) (PS)			− 0.1302	(−2.29)
(KA) (KS)			− 0.0420	(0.89)
(PA) (PH)			− 6.0331	(−2.36)
$R^2 = 0.65$, $\bar{Y} = 4022$, standard error = 1190				

[a] Including average value of dummy variables for municipios.

payoff from the fertilizer levels recommended by the alternative approaches. But these recommended levels will not, in general, be included among the experimental treatments in the evaluation subset. Hence, we are in the position of using each of the models to select the best from a finite set of fertilizer treatments, rather than the best of all possible fertilizer levels. Therefore, the procedure used is to employ the two response models to predict, a priori, the most profitable of the treatments used at each evaluation site. This is done both with and without soil test information and with and without soil classification schemes. Differences in average net returns from the treatments selected by the various approaches provide an estimate of the expected value of each approach.

The Value of the Response Models and of Soil Test Information

Table 1 shows the estimated coefficients of the quadratic model based on the pooled data from the twenty-six experiments. While a detailed discussion of the characteristics of this function are beyond the scope of this paper, the function does exhibit declining marginal product, except for potash for which there appeared to be no response. The interaction terms for applied nutrients and soil tests had the expected signs. No other functions were estimated.

The linear response and plateau (LRP) models were estimated graphically, using the procedures described by Waugh, Cate, and Nelson. In order to incorporate soil test in-

Table 2. Linear Response and Plateau Functions

Nutrient and Soil Grouping	Threshold	Slope	Nutrient Requirement[a]	Plateau
	kg/ha			
N, all soils pooled	2,954	20.38	95	4,890
P, all soils pooled	3,003	23.67	73	4,724
P, soils less than 10 ppm	2,817	25.00	73	4,641
P, soils greater than 10 ppm	no response			
K, all soils pooled	no response			
K, soils less than 70 ppm	no response			
K, soils greater than 70 ppm	no response			

[a] The nutrient level at which the plateau is reached.

Table 3. Value of Soil Test Information and the Quadratic Model versus the Linear Response and Plateau Model

Production Model	Average Net Returns for Chosen Treatment with Soil Test Information[a]		Value of Soil Test Information
	Acquired	Not Acquired	
	($/ha)	($/ha)	($/ha)
Quadratic	177.49	171.33	+ 6.16
Linear response and plateau	178.81	147.89	+30.92
Value of the quadratic model	− 1.32	+ 23.44	

[a] Realized gross crop value minus fertilizer costs for that treatment chosen a priori, averaged over twenty-eight sites.

formation into the analysis, a separate response function was estimated for soil levels above and below "critical" soil test levels for P and K (determined according to Waugh, Cate, and Nelson). Soil pH was ignored, although it would be possible to estimate separate response functions for high and low pH groupings, as well. The estimated coefficients of the LRPs are shown in table 2. The estimation procedure revealed responses only for nitrogen (for all sites pooled), for phosphate with all sites pooled and for phosphate on soils testing less than ten parts per million of P. The phosphate "requirement" (the level required to reach the plateau) turned out to be the same for all sites pooled and for low phosphorus soils.

The data necessary to calculate the value of the models and the value of the soil test information are presented in table 3. The quadratic model was used in two ways. In one case the soil test reading from each of the twenty-eight sites was entered into the response function to predict which of the treatments would give the highest net returns. In the other case, the soil test average for the fifty-four sites was entered into the function, and the resulting equation was used for all sites.[4] The average net return (gross crop value minus fertilizer costs) on the twenty-eight sites in the first case was $177.49 per hectare. The average net return in the second case was $171.33, so that the difference of $6.16 per hectare is our estimate of the expected value of the soil test information, given that the quadratic response model is used. A t-test on the twenty-eight differences indicated that this average is significantly different from zero at the 0.01 level of significance.

If soil test information is available, the appropriate LRPs are the pooled nitrogen function described in table 2 and phosphate response curve 3 or 4, depending on the soil test. The average net returns of the treatments chosen by this approach were $178.81. This is $1.32 per hectare higher than for the use of the quadratic with soil test information. Thus, the best estimate of the value of LRP (with soil tests) compared to the quadratic (with soil tests) is $1.32 per hectare, although this average is not significantly different from zero, using a t-test on paired differences as a criterion. Still, it will be surprising to some that the LRP provides recommendations as valuable on the average to the farmers as those from the quadratic function.

When the LRP approach was used without soil tests, however, the results were significantly worse. The net returns averaged only $147.89 per hectare. This is $30.92 less than the LRP with soil test information, giving the soil test information a value of $30.92 per hectare. Regardless of whether ten parts per million is an appropriate division point, it is approximately correct to say that there is no phosphorus response on soils testing higher than this.

Also from this last value, $147.89, we can see that the value of the quadratic function is very high, $23.44 per hectare, if no soil test information is to be obtained.

The Value of Soil Classification Schemes

The two soil classification schemes have already been mentioned, classification by soil phosphorus level and by geographical region.

[4] The recommended levels of N and P_2O_5 from this equation are 128 kg and 42 kg per hectare for soils with an average soil test (pH = 5.28, soil P = 13.24 parts per million).

Table 4. Value of Two Soil Classification Models versus the Alternative of Pooling All Sites

Classification Model	Average Net Returns for Chosen Treatment[a] Using the Classification Model	Pooling All Sites	Value of the Classification Model
	($/ha)	($/ha)	($/ha)
Classification by soil test, P level (soils above & below 10 ppm)	154.24	177.49	−23.25
Classification by geographical region	168.32	177.49	− 9.17

[a] Realized gross crop value minus fertilizer costs for that treatment chosen a priori (utilizing soil test information and the quadratic model), averaged over twenty-eight sites.

These schemes were evaluated using the quadratic model and assuming that soil test information was available. The twenty-six "estimation" experiments and the twenty-eight "evaluation" experiments were each divided into two groups using the classification criteria. The quadratic function was fitted to each class of soils separately and predictions were made using the appropriate function for each of the twenty-eight evaluation experiments.

The results are shown in table 4. Both of the classification schemes turned out to have a negative value as compared to the alternative of no classification scheme at all—simply pooling all sites. The average net returns fell by $23.25 per hectare when the soil phosphorus classification scheme was used, and by $9.17 per hectare when the geographical classification scheme was used.

It may seem odd that pooling together "unhomogeneous" soils could result in better predictions (and presumably better recommendations) than would separating them into more homogeneous groups for analysis. The reason no doubt has to do with sample size. In fitting a single function to soils which may differ considerably, we introduce specification bias into our estimators, and we increase variability within the system. On the other hand, by pooling these various soils the sample size is increased, thereby reducing the variance of the estimators. Consequently, the estimators may be better in mean square error for any one homogeneous soil class, even though they are biased. In the case of these data, the beneficial effects of sample size have probably outweighed the negative effects of specification error.

Conclusions

This paper has suggested an approach to determine the value of alternative response models and has applied the approach to fertilizer response data for corn in Brazil. The results show that the linear response and plateau model, even though it is of the discontinuous type not favored by economists, can provide fertilizer recommendations as valuable to the farmer as those from a generalized quadratic model. This was only the case, however, when soil phosphorus test information was available.

One cannot generalize from this result on corn response in one state. Further comparison of these (and other) models on other data would first be necessary, and unfortunately the approach described here is both time- and data-consuming. But these particular results should serve to cast some doubt on the widespread (among economists) notion that fertilizer response should always be analyzed by fitting a smooth response surface.

Soil test information is quite valuable for fertilizing corn in this area, regardless of which response model is used to generate recommendations. One should be cautioned against multiplying the value estimated here by crop area to obtain the potential value of a soil-testing service. The value measured is compared with the alternative of knowing nothing about the piece of land. But farmers have a great deal of information about their land, and the value of this information may on the average be very close to that of the soil test information. If so, the net value of the soil test information would be small.

A final conclusion is that it is not necessarily desirable to group soils into homogeneous classes in order to make fertilizer recommendations. Quite the contrary, these results suggest that variability among experimental results is so great that the value of pooling experiments, in reducing standard errors of estimators, exceeds the costs imposed by introducing specification bias into the estimators.

The two classification schemes examined were crude ones. Much more sophisticated systems for classifying soils at various levels of aggregation are available. The value of these systems for making farmer recommendations would be an interesting topic for further empirical research.

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A Risk-Programming Analysis of Forward Contracting with Credit Constraints

Peter J. Barry and David R. Willmann

A multiperiod risk-programming model is developed to evaluate forward contracting and other financial choices for farmers who are subject to market risks and external credit rationing. The model utilizes mean-variance analysis to derive sets of E-V efficient growth plans reflecting the influence of contracting on income stability, levels of credit, and income growth. A case farm is used to develop the model's decision elements and to survey the credit responses of lenders to contract choices. Model results indicate that the lenders' credit responses may modify the producer's contracting plans and his rate of income growth.

Key words: contracting, credit, firm growth, risk management, risk programming.

Increasing market risks together with rising farm debt have magnified potential losses of farmers' equity capital, hampered business planning and increased uncertainty in servicing debts and other financial obligations. Forward price contracting provides one response in risk management that removes the farmer's uncertainty of a future product price and assures greater certainty of loan repayability.[1] However, neither past research in contracting theory nor studies in financial management (e.g., Baker 1968a,b, Barry and Baker) have given systematic attention to interactions between contracting and credit.

In contracting theory, recent studies have used mean-variance analysis (Markowitz, Tobin) as a framework for evaluating optimal levels of contracting. McKinnon, for example, treated interactions between a producer's expected price risk and yield risk to determine a risk-minimizing level of contracting. Ward and Fletcher, Heifner, and Johnson used expected means and variances of returns in deriving combinations of cash positions and hedging in futures contracts that would minimize variance for a target level of returns.

These theoretical developments have focused primarily on short-run analyses for firms with fixed size, production organization, and financing programs. However, contract strategies may be modified if firm size and production organization are allowed to vary with credit becoming an effective constraint. Expanding credit becomes important and the producer may adapt his level of contracting to accommodate his lenders' preferences for greater certainty of loan repayment. Hence, it is important to establish procedures for evaluating the joint contribution of forward contracting to income stability, level of credit, and income growth.

Accordingly, the purpose of this paper is to demonstrate the development and structure of a multiperiod risk-programming model that is used to evaluate contract and other financial choices for producers who are subject to external credit rationing. Following sections describe the model's formulation, an empirical application, and a survey method used to measure credit responses of a sample of lenders to alternative levels of contracting.

The Risk-Programming Model

A multiperiod, quadratic program is used to model a firm's growth environment and to evaluate the effects of external credit rationing on optimal levels of contracting. The mathematical model is outlined below while its

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[1] Forward contracting generally specifies a price and time of delivery for either full production or a specified volume of production outside of an organized futures market. The empirical application in this study is concerned solely with contracting specified quantities of production.

more detailed features are discussed in the empirical application:[2]

$$\max U = \lambda CX - X'DX,$$

subject to

$$AX \leq B$$
$$X \geq 0,$$

where U = the value of the objective function, X = a column vector of activity levels defined over the respective time periods reflecting the firm's financial, marketing, and production choices, C = a row vector of gross margins and fixed costs defined as time-discounted values over the respective time periods, D = the variance-covariance matrix, with entries on open-market and contract sale activities defined as time-discounted values over the respective time periods, B = a column vector of the firm's resource levels and other constraints defined over the respective time periods, A = a matrix of technical coefficients for activities and constraints defined over the respective time periods, and λ = a scalar to be varied parametrically from zero to unbounded.

The model's basic structure resembles that of other growth models (e.g., Barry and Baker, Baker 1968b, Vandeputte and Baker) cast in terms of multiperiod linear programming with the addition of risk information expressed as variances and covariances on selected activities in each period. The multiperiod quadratic program consists of one matrix with years represented by submatrices of technical coefficients along the main diagonal and off-diagonal elements representing transfers of assets, liabilities, and other interyear effects. The objective function represents the summation of each year's linear and nonlinear entries over all years in the planning period. Hence, these specifications provide for a model solution that is jointly optimal over these years.

The linear portion of the objective function for each year is comprised of time-discounted expected values for gross margins on product sale activities, interest charges on debt, and depreciation charged against acquiring depreciable resources. The nonlinear portion for each year reflects time-discounted variances and covariances on gross margins of open market and contract sales—the major sources of risk to be evaluated. Interyear covariances are assumed to be zero.

The multiperiod quadratic program derives an efficient E-V solution, called a growth plan, that minimizes variance for a given net present value of income.[3] The E-V efficient growth plan prescribes production, investment, and market plans for each year in the planning period. Parametric variation of λ yields a set or frontier of E-V efficient growth plans. The last solution in the efficient set yielding maximum net present value of income from available resources is equivalent to the solution of a multiperiod linear program that differs only in the absence of the variance data.

Expected variabilities of yields and prices for resources and products are assumed to be reflected solely in objective function values for variances and covariances of gross margins on product sale activities in each year (Hazell, Rae). Constraint coefficients used to transfer assets and financial obligations from year to year are based on expected values for these respective activities and resource levels budgeted in the model. Thus, the model is designed to provide the decision maker with a set of a priori growth plans that organize the business to accept alternative combinations of risk and returns valued over the planning period. The decision maker must then choose the plan that best satisfies his preferences toward risk and returns.

An Empirical Application

A representative case farm for the Southern Blacklands of Texas is used both to develop the decision elements of the risk-programming model and to survey the credit responses of lenders to contract choices. The model's decision variables in each year include choices in producing cotton and sorghum; investing in land-machinery complements; short-term, intermediate, and long-term financing; consumption-taxation, and choices in market contracting—all in accord with choices faced by a representative producer in the Texas Blacklands. Annual and seasonal constraints include resource limits on land, machinery,

[2] Parametric quadratic programming can be formulated in several ways. This formulation follows that of Hadley and Sharpe with an algorithm programmed for computation by Cutler and Pass.

[3] Critics (Borch, Feldstein) of the mean-variance approach contend that it is only applicable if a manager's utility function is quadratic, reflecting preferences toward mean and variance of expected returns, or if he regards uncertain outcomes as normally distributed. Nonetheless, mean-variance analysis was judged suitable in this study for testing the response of contract strategies and income growth to external credit rationing.

Table 1. Production, Contract, and Financial Components for Year One of the Quadratic Programming Model

	Produce for		Contract Choices				Purchase Land-Machinery	Borrow	Consume and Tax	Cash-Transfer		Relation	Constraint Level
	Market Sale	Contract Sale	Total	Two-Thirds	One-Third	None							
Constraint	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}		
Income	C	C					$-C$	$-C$				=	max
Period 1													
Beginning cash	A	A						-1	A	1		≤	B
Ending cash	$-A$	$-A$						$1 + i$	A	-1	1	≤	0
Credit			$-3A$	$-3A$	$-3A$	$-3A$	A	A				≤	B
Market sale	-1		0	1	2	3						=	0
Contract sale		-1	3	2	1	0						=	0
Land-machinery	A	A					$-A$					≤	B
Consume	C	C					$-C$	$-C$	1			=	0
Period 2													
Beginning cash											-1	≤	0
Ending cash							A					≤	0
Credit							$\pm A$					≤	B
Land-machinery							$-A$					≤	B
Consume							$-C$					=	0

cash, credit, and requirements for consumption and taxation. Market requirements force production to be sold through one or more of the contract choices. Table 1 summarizes the linear portion of the model's structure for the first year and the transfer effects in the following year. Coefficients requiring empirical observation are defined in letter notation. Adding the variance-covariance data (table 2) on the market (X_1) and contract (X_2) sale activities in each year provides the quadratic formulation.

Specification of Financial Components

Growth in income-generating capacity occurs by acquiring additional resource capacities. Land-machinery investments add to resource capacities in the purchase year and in subsequent years, require loan financing, and reduce annual income to the extent of annual depreciation. Intermediate and long-term loans provide financing for investments. Credit is reduced by loan financing in the purchase year and is further modified in following years as asset equity is increased by debt repayments and by the appreciation and depreciation of asset values. Debt servicing requires principal and interest payments at specified time intervals with interest reducing annual income.

Short-term borrowing uses non–real estate credit to supplement cash flow through the year, requires payment at year end, and reduces income to the extent of interest paid. Cash activities transfer surplus cash through the year and to the following year. Family consumption and taxes are specified respectively by a declining marginal propensity to consume and a progressive tax rate structure (Vandeputte and Baker).

Non–real estate credit generated by income expected from product sales, including lenders' responses to contracting, is reflected in constraint coefficients for contract choice activities. Non–real estate credit provided by

Table 2. Variance-Covariance Matrix for Cotton and Sorghum Sales

	Market Sale Cotton (MSC)	Contract Sale Cotton (CSC)	Market Sale Sorghum (MSS)	Contract Sale Sorghum (CSS)
MSC	3,672	2,603	2,047	1,942
CSC	2,603	2,796	1,836	1,742
MSS	2,047	1,836	1,855	1,465
CSS	1,942	1,742	1,465	1,545

machine and other non–real estate collateral is reflected in right-hand-side values and in constraint coefficients for investment-financing activities. Real estate credit available to finance land purchases is specified separately.[4]

Specification of Production, Sale, and Risk Components

Production and sale of cotton and sorghum provide the major sources of risk and returns. Production uses land and beginning cash for growing crops, generates ending cash and net income, and requires open market and/or contract sale. Forward contracting is assumed to reduce both the level and variability of a producer's expected product prices. Reductions in price expectations reflect costs of contracting including the expectations of a price premium by forward buyers or speculators as reward for their acceptance of greater risk. To reflect lower price expectations, expected open market prices on each crop were set 10% above their contract prices in deriving expected gross margins for market and contract sales.[5]

Contracting prior to the harvest season was also expected to remove the producer's risk of seasonal price variation. Hence, variance-covariance entries on contract sale activities (X_2) reflect estimates of total variability of gross margins less the portion attributed to seasonal price variation. Entries on market sale activities (X_1) reflect estimates of total variability of gross margins.

Annual variances and covariances for gross margins of cotton and sorghum were derived from time-series observations of farm-level yields and prices. Weekly prices during harvest seasons were collected over the 1964–73 period. Annual yields were collected using farm-level data from a university farm in the study area. Estimates of variable production costs were obtained from secondary sources and deducted from the product of weekly prices and annual yields to provide weekly or seasonal time series of estimated gross margins.

Estimates of variability derived from these time series reflected jointly the effects of annual yield and price variation, seasonal (weekly) price variation and other random factors. No significant trends in annual gross margins were measured for these data sets over the period of observation. Estimates of seasonal price variation were obtained by averaging annual estimates of seasonal price variation over the entire time series and also by deriving seasonal measures of more recent years that were less influenced by government programs of price support and supply management. Model results reported here are based on the assumption that contracting will remove seasonal price variation as measured over the 1972–73 time period. For this time period, seasonal price variation comprised 23.8% and 16.7% of total variability in gross margins for cotton and sorghum, respectively. The estimated variance-covariance matrix is given in table 2.

Specification of Contract-Credit Components

Activities X_1 through X_6 (table 1) indicate the method of specifying interactions among production, contract choices, and credit. Four contract choices are specified: X_3 total contracting; X_4 contracting two-thirds of expected production; X_5 contracting one-third of expected production; and X_6 no contracting. The number of contract choices in the model corresponds to the number of contract choices evaluated in the lender survey.

Coefficients in the credit row reflect the rates at which credit is generated by the respective levels of contracting. The specification of coefficients in market and contract constraints for produce-sale and contract-choice activities together with zero level requirements assures that one or more contract choices will enter the solution at levels totaling one-third of levels in the production activi-

[4] Initial constraints include 275 acres of cropland valued at $450 per acre and appreciating at an annual rate of 8%. Each acre of purchased land is comprised of 0.8 acre of cropland and 0.2 acre of rangeland. Machinery investments of $60 per acre of purchased land are also required. Objective function values were discounted at an 8% rate to determine present values. Cost and return data for crops were developed from extension service budgets. Additional detail on model specifications is available from the authors.

[5] The very assumption of lower price expectations on contract sales has a greater potential impact on model results than does the exact magnitude of the reduction. Open market sales are then more profitable and, when credit effects are ignored, will tend to dominate the higher income solutions. Hence, the 10% margin is arbitrarily selected to reflect costs of contracting, including an expected risk premium. Most studies of price relations in forward sales have treated expected cash and futures prices in commodity futures markets (Gray and Rutledge). The implications for existence and size of risk premiums appear mixed, ranging from theoretical arguments supporting positive returns for the speculative function of risk bearing to empirical studies indicating little or no evidence of risk premiums. In this study, we assume that the market firm or speculator accepting a portion of the farmer's risk through the forward contract does expect to receive a premium for carrying the greater risk.

ties.[6] For no contracting, X_6 enters the solution at level ⅓ X_1. For one-third contracting, X_5 will enter the solution at level ⅓ $(X_1 + X_2)$ with X_1 double the level of X_2. Contracting one-half the crop could occur from a combination of contract activities yielding equal levels of X_1 and X_2. Other levels of contracting could occur in a similar manner.

The level of contracting in each E-V efficient solution depends jointly on the target level of income in the growth plan and its credit requirements, on the need for variance minimization, and on the relative rates of credit generation in the credit rows. If lenders do not discriminate among contract choices in their credit responses, contracting levels would depend solely on the price and variance effects associated with contracting. Moreover, as higher levels of income are sought by increasing λ, contracting should become less favorable relative to open market sales due to its lower price expectations.

When lenders do discriminate among contract choices in their credit responses, results depend on the value of credit in the solution. At low levels of income where credit is not constraining, contracting levels will again depend solely on price and variance effects. However, as higher levels of income are sought by increasing λ, there will be a tendency for contract levels with higher rates of credit generation to enter the solution in early years of the planning period to provide financing for greater growth.

Some caution is needed for interpreting levels of contracting (e.g., one-half the crop) that differ from those choices specified in the model. Since rates of credit generation for each choice are based on lender responses to those respective levels of contracting, a model solution indicating combinations of contract choice activities would in effect be averaging the credit responses given by lenders for other levels of contracting. When these levels of contracting occur, one must accept the assumptions that lender responses are linear and continuous between the levels specified in the model.

Measuring Credit Responses to Contracting

The basis for expecting lenders to discriminate among the borrower's contract choices rests on their preferences for greater certainty of loan repayment. Moreover, differences in contracting preferences between lender and borrower may arise from their differing risk positions in the loan transaction. The borrower participates directly in any gain or loss arising from the loan. The lender, however, is restricted to the returns, interest and principal, established in the debt contract. He only indirectly benefits from profits through the borrower's growth in financing needs over time. In addition, the lender's prior claims on the borrower's expected income and assets pledged to secure the loan request increase the borrower's financial risk.

Measures of credit responses to contracting were obtained from a sample of bankers and production credit associations who evaluated a case loan request with the interviewer simulating the manager of the representative cotton-sorghum farm. The simulated borrowing method has proved useful in prior research as a method of estimating a firm's total credit and evaluating lender responses to various managerial choices in a firm's financial and production organization (Baker 1968a, p. 507, 1968b, p. 1566). It provides a realistic setting for the lenders' credit evaluation and permits the interviewer to more directly control the variation of factors used to elicit the lenders' responses.

Banks included in the study were selected randomly from the study area. During the survey, some banks were deleted without replacement because of either inactivity in agricultural lending, lack of familiarity with contracting, or inability to provide a definitive credit response. Hence, credit responses were obtained from eight cooperating lenders who make agricultural loans and have some familiarity with contracting. While the sample is small and somewhat restricted in scope, it likely offers a representative profile of primary lending sources available to the case farm.

The case loan request included financing needed for operating expenses, debt servicing, and new capital investments. Loan documentation included three years of historical balance sheets, income statements, and flows of funds—accounts demonstrating the farmer's management and business performance. To test responses to contracting, projected cash flows in the loan request were budgeted under the four forward contracting alternatives described earlier. The loan request was set high enough to anticipate the lender's rejection and designed for deletion of individual capital

[6] This specification of coefficients in market and contract constraints requires that per acre rates of credit generation be multiplied by a factor of three when introduced in the model. The factor will vary with the number of contract choices in the model.

Table 3. Results of Lender Survey for Alternative Levels of Contracting

	Proportion of Crops under Contract			
	Total	Two-thirds	One-third	None
1. Operating loan request	54,460	54,460	54,460	54,460
2. Capital loan request	40,350	40,350	40,350	40,350
3. Total loan request (1 + 2)	94,810	94,810	94,810	94,810
4. Average loan granted	74,745	87,593	83,866	77,168
5. Asset credit	50,647	50,647	50,647	50,647
6. Crop credit (4 − 5)	24,098	36,946	33,219	26,521
7. Cotton credit per acre	54	82	74	59
8. Sorghum credit per acre	36	55	49	39

items until loan approval was obtained. Lenders were asked to designate their preferred level of contracting together with its loan limit and then indicate maximum loan limits for each of the other levels of contracting.[7]

Table 3 reports the size of the loan request (line 3) and the average of the lenders' loan limits (line 4) for each level of contracting. The loan limits are expressed in total dollars and in dollars per crop acre. To utilize the loan limits in the risk-programming model, coefficients of credit generated per crop acre were derived by deducting credit of $50,647 assumed to be generated by the borrower's equity in non–real estate assets available for loan security and allocating the remaining credit among cotton and sorghum according to their relative acreages and gross margins as budgeted in the loan request.[8] This allocation provides a more precise delineation of credit generated by income expected from crop sales.

Survey results indicate that larger loan limits are associated with contract choices X_4 and X_5, suggesting that an intermediate level of contracting is preferred to all or none. Two-thirds contracting exhibited higher credit than one-third contracting, and no contracting exhibited higher credit than total contracting. Analysis of variance indicated that differences among the per acre loan limits for the four contracts were statistically significant at the 2.5% level.[9] Lenders were not asked to justify their credit responses. Still they volunteered numerous observations and opinions that tended to be consistent with these credit responses.

Results Derived from the Risk-Programming Model

Efficient E-V frontiers are derived for a growth horizon of four years with model specifications on non–real estate credit that exclude and include the lenders' credit responses to contracting. The four year horizon was short enough to be computationally feasible for the quadratic program and long enough to observe time patterns of investment and contracting. Excluding the credit responses by specifying credit generation only at the rates for no contracting reflects nondiscrimination by lenders toward contract choices and provides a comparative basis for model solutions.

Tables 4 and 5 report acres purchased, total crop acres, contracting percentages, credit constraints, and objective function values of selected E-V solutions for the two model specifications.[10] The final solutions represent the income-maximizing plans at the peak of the E-V frontiers.

E-V frontiers are identical at low levels of income where credit is not constraining. Solutions in this range are generally characterized by relatively high levels of contracting, little or no land investment, and small diversification

[7] Additional contract levels (e.g., one-fourth or one-half of crop) could have been specified; however, more numerous levels of contracting would severely tax the lender's capacity to evaluate the case loan request. Also, lenders could have been left free to choose any level of contracting. But, specifying the four choices provided a more precise means of quantifying credit responses for the risk-programming model.

[8] Rates of credit generation per acre of cotton were assumed to be 50% greater than those for grain sorghum to accord with a similar ratio of gross margins for the two crops. However, in the case loan, sorghum acreage (336 acres) was 50% greater than cotton acreage (224 acres). Thus, each crop is expected to provide one half of the firm's total gross margin. To allocate credit among each crop, total crop credit (table 3, line 6) was divided in half and then further divided by the respective crop acreage.

[9] The analysis of variance utilized a completely random design with the four contract choices serving as treatments and the eight lender responses to each contract choice serving as replications. An F-distribution was hypothesized for the sample statistic with 3 (numerator) and 28 (denominator) degrees of freedom.

[10] The quadratic program yielded forty E-V efficient solutions when credit responses were excluded and fifty-one solutions when they were included. Six of these solutions are reported for each model variation.

Table 4. Results of Quadratic Programming When Lenders' Credit Responses to Contracting Are Excluded from the Model

Solution		Acres Purchased	Total Crop Acres	% Contracted	Credit Constraining: Non-Real Estate	Credit Constraining: Real Estate	Present Value: Income (E)	Present Value: Standard Deviation ($V^{1/2}$)
1. Year	1	0	275.0	66.6	no	no	92,366	26,627
	2	0	275.0	66.6	no	no		
	3	0	275.0	66.6	no	no		
	4	0	275.0	66.6	no	no		
2. Year	1	91.4	348.1	50.8	no	no	117,407	35,511
	2	0	348.1	51.1	no	no		
	3	0	348.1	51.5	no	no		
	4	0	348.1	51.6	no	no		
3. Year	1	170.5	411.4	44.8	yes	no	165,244	55,490
	2	216.6	584.7	49.1	yes	no		
	3	0	584.7	49.4	no	no		
	4	0	584.7	49.7	no	no		
4. Year	1	160.7	403.5	16.8	yes	no	201,217	74,757
	2	219.3	579.0	32.2	yes	no		
	3	221.3	756.0	39.4	yes	no		
	4	372.5	1054.0	47.6	yes	no		
5. Year	1	155.0	399.0	0	yes	no	204,272	77,300
	2	209.8	566.8	0	yes	no		
	3	223.9	745.9	15.5	yes	no		
	4	374.3	1045.4	33.2	yes	no		
6. Year	1	155.0	399.0	0	yes	no	206,350	80,208
	2	209.8	566.8	0	yes	no		
	3	213.7	737.7	0	yes	no		
	4	354.9	1021.7	0	yes	no		

among cotton and sorghum with cotton dominating. However, for higher levels of income (beyond solution 2) credit becomes constraining and the lenders' credit responses cause the E-V frontier to shift right and reach a higher level of income. These solutions specialize in cotton and can be contrasted by level and timing of contracting and land investment.

For excluded credit responses (table 4), solutions higher on the E-V frontier exhibit successively lower percentages of contracted production with the decline beginning in early years of the planning period. Contract sales decline because of their lower income expectations. The decline is initiated in early years because discounting to derive present values of income and variance favors higher returns from open market sales in those early years. Acreage purchased increases through solution 4 and then declines somewhat in subsequent solutions reflecting income trade-offs between lower levels of acreage and higher proportions of open market sales. The final solution yielding maximum net present value of income of $206,350 with standard deviation of $80,208 contains no contracting.

When the discriminating credit responses of lenders are included in the model, higher contracting in earlier years of the planning periods together with rapid growth in the land base characterize solutions all along the E-V frontier. Moreover, the proportion of contract sales remains relatively high in all E-V efficient solutions, declining somewhat at higher points on the frontier. Even the income-maximizing solution contains relatively high levels of contracting. These results contrast directly with the decline in contracting initiated in early years of solutions obtained with nondiscriminated credit responses. The relatively higher proportion of contracting in early years of the planning period generates greater credit thereby expanding debt-servicing capacity for purchasing land and machinery. Larger purchases of land and machinery in turn provide for growth in present values of income from production over the entire period. In the income-maximizing solution, the additional credit provided by contracting increases the net present value of income to $271,966 with a standard deviation of $105,281.

Concluding Comments

This risk-programming model has been formulated to provide a general method of integrat-

Table 5. Results of Quadratic Programming When Lenders' Credit Responses to Contracting Are Included in the Model

Solution		Acres Purchased	Total Crop Acres	% Contracted	Credit Constraining: Non–Real Estate	Credit Constraining: Real Estate	Present Value: Income (E)	Present Value: Standard Deviation ($V^{1/2}$)
1. Year	1	0	275.0	66.6	no	no	92,366	26,627
	2	0	275.0	66.6	no	no		
	3	0	275.0	66.6	no	no		
	4	0	275.0	66.0	no	no		
2. Year	1	91.4	348.1	50.8	no	no	117,407	35,511
	2	0	348.1	51.1	no	no		
	3	0	348.1	51.5	no	no		
	4	0	348.1	51.6	no	no		
3. Year	1	391.4	588.2	57.6	yes	no	179,482	59,888
	2	0	588.2	50.4	yes	no		
	3	0	588.2	50.7	no	no		
	4	0	588.2	51.1	no	no		
4. Year	1	428.8	618.1	66.7	yes	no	252,226	92,433
	2	302.8	860.3	51.3	yes	yes		
	3	255.0	1064.3	47.5	yes	yes		
	4	0	1064.3	47.9	no	no		
5. Year	1	428.8	618.1	66.7	yes	no	267,822	101,320
	2	302.8	860.3	51.3	yes	yes		
	3	255.0	1064.3	31.5	yes	yes		
	4	324.4	1323.8	42.3	yes	yes		
6. Year	1	428.8	618.1	66.7	yes	no	271,966	105,281
	2	302.8	860.3	51.3	yes	yes		
	3	255.0	1064.3	31.5	yes	yes		
	4	324.4	1323.8	4.3	yes	yes		

ing the problem dimensions of time, uncertainty, and a firm's organizational detail in evaluating forward contracting under external credit rationing. The model's structure and data requirements can be readily adapted to study other specifications on objectives, contract and investment choices, income and variance expectations, and kinds of commodities. Including sequential opportunities for contracting through the growing season would be a useful extension. The effects on credit, risk, and income of hedging with futures contracts could also be compared with forward contracting. Storage activities could be added to evaluate the joint contribution of forward sales and buffer stocks to reducing variability of income (McKinnon). Moreover, the procedure for measuring lenders' credit responses can include other choices in risk management and can be applied to lending institutions and farms differing in size, capital structure, type, and location.

The empirical application has contained a set of specific model specifications with results largely determined by relative magnitudes of the lenders' credit responses, price and risk reduction effects for contracting, and the discount rate. The model's results for these specifications indicate that when credit is valuable, optimal growth plans will include contracting even for managers with little or no aversion to risk and even though profit possibilities based on expected market prices appear more favorable with open market sales. Hence, it is clear that research and counseling programs with agricultural producers and their lenders on the merits of contracting as a market instrument should include some treatment of the credit effects (Barry).

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Notes

The Differential Impact of Food Inflation upon the Poor

Loraine Donaldson

The poor spend a larger percentage of their incomes on food, and thus food inflation affects the poor more than higher income groups. A price index for foods purchased by the poor based on data gathered in Atlanta, Georgia—a fairly representative metropolitan area—is presented. It suggests that the cost of living of the poor during recent periods has been differentially affected by a larger increase in the price of their weighted food market basket compared to the increase in the average consumer's food market basket. A measure is also given of the degree to which food stamps failed to maintain constant purchasing power in Atlanta because of the rapid price changes.

The Index

Donaldson and Strangways (1971) compiled a weighted food market basket for the poor based on a year's accounting records of purchases at a supermarket located in a low income area of Atlanta. The annual average family income in the predominately black area in 1969 was $3,500, and 81% of the families had incomes of $5,000 or below. The market basket for people with incomes somewhat above as well as below the poverty line is distinctly different from the market basket of the average consumer as measured by the Bureau of Labor Statistics (BLS). While the poor may purchase some of the same items as the average consumer, invariably such common items make up a different weight or percentage of total purchases. And the poor purchase many items, such as pigsfeet, fatback, hog jowls, and neckbones, as well as cheaper brands of groceries not included in food lists of the BLS, because thery are not bought by the average consumer.

Prices in 1969 form the base period. In compiling the index, 112 products were priced on the same day of the same week of each month for one year. All chains with outlets in the vicinity of lower income census tracts within the city were represented in the index. The index is not seasonally adjusted, nor is the Atlanta BLS index to which it is compared. Inasmuch as produce accounts for less than 10% of the total index, seasonality does not have a large impact. However, the meat index and the total index are influenced by the seasonality of pork items. To date, no other statistically reliable index of this type has been established for other geographical areas. While the index reflects purchasing patterns of a predominately black poverty situation, the relative weights given to types of categories of items and most of the items used in those weighted categories will represent the price inflation impact upon other nonblack poor.

The difference between what the poor paid for food in 1974 compared to 1969 and what the average consumer paid will be larger than indicated by the differences in the index. There are several reasons for this. First, the composite BLS index includes both chains and independent groceries. The index for Atlanta's poor is a composite index that includes only chain stores. Independent ghetto stores have increased prices more than chain stores as can be seen from indexes for specific stores (table 1). Closely connected to the fact that the index for the poor would be higher if independent grocery outlets were included is the fact that the poor are more likely to spend a larger percentage of their food budget at independent stores than the average consumer because of the location patterns of chains in Atlanta and the relative immobility of the poor (Donaldson and Strangways 1973, p. 64). Thus, independents would tend to be more heavily weighted in the composite index of Atlanta's poor than in the BLS index if exact data were available.

Second, the poor have limited substitution possibilities in their budget because they already buy in the relatively least expensive categories of dietary needs. The average family can switch among items, changing to those that have increased less, and can diminish its total consumption of food and/or eat less of more expensive categories of food, such as better cuts of meat, by substituting less expensive protein sources—without loss of dietary standards necessary for good health. The BLS index does not account for the substitution of this type that goes on during periods of rapid inflation.

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Table 1. Food Price Index Comparisons: Atlanta BLS Compared to Index for Atlanta's Poor

	1973 Dec.	1974 Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	1975 Feb.
	(August 1969 = 100)												
Food At Home													
BLS (Atlanta)	140.3	142.5	147.3	150.0	148.9	149.0	148.5	148.6	152.6	156.1	158.3	160.3	163.3
Atlanta's poor[a]	151.0	151.8	155.4	158.3	155.0	152.6	152.0	155.4	159.3	163.7	165.0	170.3	174.0
(with nonfood)[b]	148.2	148.9	152.1	154.6	151.7	150.0	150.1	153.6	157.3	161.6	163.0	167.7	171.7
(independent)		154.5[c]	162.3[d]	176.3[e]									
Groceries													
BLS (Atlanta)	138.5	140.8	145.2	147.9	149.5	149.0	148.3	151.0	156.1	158.9	163.1	165.7	174.2
Atlanta's poor[a]	147.9	146.2	151.5	155.7	158.7	156.6	162.2	162.6	169.3	176.5	178.4	186.4	194.3
(with nonfood)[b]	143.3	142.1	146.3	149.8	152.2	151.4	156.9	158.2	163.8	170.2	172.3	178.8	186.4
(independent)		164.2[c]	159.9[d]	161.4[e]									
Produce													
BLS (Atlanta)	132.1	136.4	139.4	146.4	148.2	162.0	161.5	156.3	147.7	147.0	146.5	149.4	149.4
Atlanta's poor[a]	135.0	146.7	144.5	151.3	138.6	155.9	147.4	159.4	148.1	143.5	148.7	154.3	135.4
(independent)		129.5[c]	136.1[d]	185.0[e]									
Meat, Poultry, Fish													
BLS (Atlanta)	149.6	151.0	158.2	154.7	148.0	143.0	139.4	139.7	147.9	154.6	154.6	154.6	150.1
Atlanta's poor[a]	159.7	160.8	163.6	163.6	154.3	146.4	139.9	144.8	149.1	152.1	151.4	153.0	156.7
(independent)		147.9[c]	172.2[d]	198.8[e]									

[a] Index includes prices for chain stores only. BLS index includes independents.
[b] Includes nonfood items—cigarettes, soap, toilet paper, etc., purchased at grocery stores by the poor, weighted according to their relative importance.
[c] Downtown without nonfood (area with high competition for meats, poultry, and fish).
[d] Techwood without nonfood (formerly A&P).
[e] Ashby-Simpson without nonfood.

Finally, the poor benefit less from specials. Specials are run on items likely to attract the typical consumer, not the poor. The average family is able to "stock up" on food offered as specials. The poor are much less able to travel to bargain stores, do not have enough money to buy ahead, and usually lack freezer space for storage.

Disparate Inflation Impact

The index for Atlanta's poor and the Atlanta BLS index, as well as a breakdown into indexes for meat, poultry and fish, produce, and groceries, are shown in table 1. Prices jumped by 50% from August 1969 to December 1973 for the poor and by 40% for the average consumer. The difference between the two indexes is measurable in both the groceries and meat-poultry-fish price categories. However, a year later, in November 1974, the difference in the indexes was traceable in much greater part to higher grocery prices for the poor, which were 86% above 1969 prices compared to 66% for the average consumer. For the twelve-month period, December 1973 through November 1974, the BLS index averaged 150.2, while the index for Atlanta's poor averaged 157.5. Thus, during this period, the poor paid 5% more for food than the average Atlanta consumer.

Foods that added the most to the groceries index rise between August 1969 and December 1973 were canned vegetables, lard, sugar, canned fish, milk, eggs, bread and packaged pound cake, macaroni, spaghetti, rice, and dried beans. The subsequent large rise in the groceries index to 194.3 in February 1975 from the December 1973 level of 147.9 was a pervasive upward movement fed in part by the sugar and oils shortages. Sugar alone is heavily weighted in the index for the poor, and the price of sugar also affected other heavily weighted items including syrup, jelly, vanilla wafers, pound cake, bottled soft drinks, and canned fruits and drinks. Other important contributors to the further index climb were canned vegetables, bread, relishes and dressings, lard, shortening, margarine, peanut butter, evaporated milk, corn meal, and grits. One heavily weighted grouping—macaroni, spaghetti, rice, and dried beans—declined substantially between the end of 1974 and February 1975. Produce contributed much less to the index rise than groceries and meat, poultry, and fish. The 1969 weight for produce is 8.67 in contrast to 56.73 for groceries and 34.57 for meat, poultry, and fish.

Between August 1969 and December 1973, all meats advanced in price with salt fatback, streak-of-lean, pigsfeet, pork neckbones, and oxtail recording the highest percentage rises. Further rises in hamburger, stew meat, ham, and fryers brought the meat index to its peak in February 1974. The decline of the meat, poultry, and fish index from

Table 2. Price Indexes for Individual Food Items (Aug. 1969 = 100)

Item	1973 Dec.	1974 Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.
Canned fish	203	201	202	202	208	206	221	222	206	216	214
Sugar	169	183	199	243	248	264	305	362	416	434	511
Rice, macaroni, spaghetti, dried beans	214	218	221	226	223	229	224	221	221	213	216
Flour	169	171	192	191	188	182	180	176	176	172	175
Lard	227	228	241	255	249	220	183	251	270	288	320
Corn	157	156	185	147	177	173	184	158	166	161	164
Bread	157	157	160	171	163	185	175	172	174	174	156
White potatoes	171	192	217	168	257	202	200	164	136	147	127
Hamburger	181	223	200	194	158	154	148	167	175	178	153
Stew meat	161	181	165	174	177	165	159	166	173	180	176
Offal pork[a]	218	207	205	190	170	160	163	170	185	179	198
Pork neckbones	230	229	232	226	199	179	197	203	173	201	218
Fryers	146	156	161	148	149	130	154	149	167	159	157
Oxtails	206	218	206	169	169	167	148	123	142	158	166

[a] Represented by streak-of-lean, fatback, pigsfeet.

163.6 in February 1974 to 156.7 one year later is traceable to declines in beef, particularly oxtails and hamburger, and to a lesser degree, declines in ham and bologna. In contrast, the low for this index of 139.9 in June 1974 reflects seasonal variations in pork and a decline in chicken prices in addition to the decline in beef. Drops in pork prices (except for spareribs, which experienced increases) accounted for 52% of the price declines from February to June, and chicken and beef for 24% each. Chicken and pork prices account for the subsequent rise of the index.

Price movements in the meat, poultry, and fish index help to explain the movements of the price index for the poor relative to the Atlanta BLS index. Chicken has a weight twice as large in the index for the poor, pork three times as large, while the weight used for beef is a little less than half that used for the BLS index. Of course, the meat cuts priced in the beef and pork categories differ also.

The difficulty of the poor in substituting among the basics they buy is illustrated in table 2. Individual indexes for food items which carry a heavy weight in the market basket have increased most in price. At the same time, the substitution effect as the average consumer switches to less expensive items contributes to the rise in the index of the poor. In the case of the meat index, additional linkage effects led to higher price rises for cheaper cuts not within the substitution pattern of the average consumer as grocers rearranged profit margins on a joint product.

As prices on meat rose, average consumers switched to cheaper cuts of meat, increasing their purchase of pork relative to beef, although few switched to offal products such as pigs' ears, pigsfeet, chitterlings, fatback, jowls, etc. This led to increased margins for pork chops, hamburger, ham, and chuck roast, but reduced margins for higher priced rib roast. As consumer resistance stiffened in response to rising meat prices and a period of retail price controls was enacted, farm prices continued to rise and grocers felt pressures on meat profits. Since chains do not cater to the poor, the easiest items to increase in margin were the lowest volume, lowest priced meats, including offal products bought by the poor. Such items show the highest margin increases (table 3).[1] Profit margins on pork relative to beef widened even further than the data indicate since there is little wastage on pork compared to beef.

The substitution and profit margin effects upon meat prices help explain the difference between the twelve-month meat index averages of 149 for the BLS and 153 for the poor. As a result of rising carcass prices and pricing responses to the average consumer's buying patterns, there are no longer any "cheap" meats for sources of protein in the sense that offal pork products, fish, chicken wings, backs, etc. are all priced higher relative to more expensive meats and relative to the income level of the poor. Even such standby sources of protein as beans and peanut butter have risen significantly.

Differences in the cost-of-living impact between the poor and the average consumer are more pronounced than the index differences in price changes in the market baskets of the two groups. Recent data indicate the poor spend between 35% and 40% and even more of their income on food (USDA). Middle income families spend between 15% and 20% of their income (10.4% to 12.9% for food at home), the near poor between 23% and 27%, and the upper income families spend 10% or less on

[1] Some independent stores in the downtown area and one small chain kept their pork prices on cheaper items much lower relative to large chains than in 1969. Both the manager of an independent store and of the small chain indicated that while they were competing for the business of the poor with lower prices, these were not loss leaders and their pork margins were not below normal during this period.

Table 3. Retail Meat Margins and Relative Changes, 1969–74 (Markup over Wholesale Price as a % of Wholesale Price)

	Weight in Index of Poor (1969 survey)	Aug. 1969	Dec. 1973	Change 8/69–12/73	July 1974	Change 8/69–7/74
Beef (U.S. choice)	5.29					
Sirloin steak	0	81.7	101.4	+19.7	71.2	−10.5
Porterhouse steak	0	103.9	121.8	+17.9	78.2	−25.7
Rib roast	0	113.2	98.6	−14.6	97.9	−15.3
Round steak	included	117.7	121.7	+4.0	137.8	+20.1
Chuck roast	in total	64.3	84.8	+20.5	85.7	+22.4
Liver (average select and regular)	along with hamburger,	94.0	68.0	−26.0	186.2	+92.2
Oxtail	stew meat	135.0	64.3	−70.7	328.6	+193.6
Pork	19.05[a]					
Bacon	0	134.4	154.6	+20.2	150.0	+15.6
Picnic ham	1.41	57.6	76.5	+18.9	82.2	+24.6
Pork chops (14/12 lb)	4.59	86.4	108.5	+22.1	149.7	+63.3
Spareribs (average 3/12 lb and 3/5 lb)	3.17	49.0	88.7	+39.7	71.0	+22.0
Neckbones	2.12	113.7	218.2	+104.5	364.5	+250.8
Streak-of-lean (average 30/35 lb and 40/50 lb)	3.17	76.1	164.1	+88.0	400.0	+323.9
Fatback (average 10/12 lb and 18/20 lb)	3.17	85.4	112.8	+27.4	n.a.	n.a.
Pigsfeet	3.17	172.7	216.9	+44.2	263.6	+90.9

Note: Retail item prices from this study and BLS. Wholesale prices are from the National Provisioner, listing daily wholesale prices for Chicago packers. A monthly average of prices is used and, in periods of large changes, is lagged. While these data do not represent any one store, they are indicative of differences over the period.
[a] Also includes fresh ground pork sausage (3.17) and hindleg ham (1.41).

food, including food away from home. Based on 1960–61 quantity weights but allowing for price changes since that time, the BLS cost-of-living index for urban wage earners and clerical workers showed food at home represented 17.8% of all items in December 1973 and 18.3% in December 1974 in Atlanta.

For purposes of comparing the diminution in purchasing power resulting from food inflation, a range of 16%–22% is chosen to represent the food cost-of-living component of expenditures for an average family and 35%–40% for the poor, and it is assumed that all food is consumed at home. The percentage price rises in the indexes from table 1 are multiplied by the cost-of-living percentage ranges to give an estimate of the disparate impact of food inflation upon the poor (table 4). The contribution of food to the rise in the cost of living of the poor was approximately 26% between August 1969 and November 1974, fifteen percentage points more than its contribution to the average family's cost-of-living increase. One-fourth of the fifteen-point difference is traceable to higher rises in the food price index for the poor. This is a conservative estimate of the differential impact for the reasons given earlier. Some of the immobile poor, shopping at less competitive ghetto independent stores may have experienced a budgetary erosion three times that of the average consumer.

Food Stamps

The food stamp program has alleviated some of the distribution effects of higher food prices, although during the period covered, over half the lower income and poor who were eligible did not receive stamps. Stamp recipients above certain minimum income levels receive varying subsidies according to their adjusted income and family size. Those in the upper ranges of income eligibility recoup some if not all of the differential between their cost-of-living increase and the average consumer's.[2] Those

[2] For example, assume the only distributional effects stem from changes in food prices, and consider two families. An average family is assumed to have a monthly income of $1,000 and spend 20% on food; the low income family is assumed to have a $350 monthly income and spend 35% on food. As a result of higher food prices, the cost of base year food purchases for the average income family rises to $300, a cost-of-living increase of 10%, while the cost of the lower income family's food rises to $280, a 21% cost-of-living increase. For the lower income family to experience the same 10% cost-of-living impact as the average family, their expenditures on the $280 worth of food would have to be held to $225. Assume the food stamp allotment for the family considered here is $150—the amount available to a family of four in the second six months of 1974. If the eligible family was required to pay $95 for the stamps, receiving a $55 subsidy, there would be no adverse distributional effects upon the family as a result of the food inflation. A subsidy of $55 was possible in 1974 for a family making $500 a month so long as its allowable deductions in arriving at eligible adjusted income were large enough. (If there were no allowable deductions, the family would have paid $126 for the

Table 4. Food Inflation Cost-of-Living Impact

	Aug. 1969 to: Mar. 1974	Aug. 1969 to: Nov. 1974
	%	
"Average family" using BLS index for Atlanta	8–11	9.6–13.3
Index for Atlanta's poor	20.4–23.3	24.6–28.1
Atlanta's poor using the BLS index	17.5–20	21.1–24.1
Atlanta's poor using index of ghetto independent store	26.7–30	—

receiving the highest subsidies are the most heavily protected from inflation under the stamp program. But, stamp recipients have experienced variations in the purchasing power of the stamps, and this in turn affects the degree of protection from food inflation and its distribution effects.

The dollar allowance per family under the food stamp program during the period covered was based upon the U.S. Department of Agriculture's economy food plan and was adjusted semiannually, with a six-month lag, for changes in the cost of this food plan. Inasmuch as the economy budget is created by the USDA and is composed of a small grouping of items designed to cover at minimum cost certain basic food needs for families, it does not reflect the actual purchasing patterns of the poor. The data for Atlanta's poor show variations in prices as high as 3% monthly, up to 6.8% quarterly, and a six-month rise of 12% from June to November 1974. Food stamp allotments for a family of four increased from $142 per month during the first six months of 1974 to $150 during the second half, an increase of 5.6%; and the yearly adjustment from January 1974 to January 1975 was from $142 to $154 per month, an increase of 8.5%. Thus, during 1974, the poor's food inflation index outpaced the increase in food stamp value, and the purchasing power of the stamps during individual months and quarters varied considerably. The importance of the discrepancy for the very poor varies inversely with the adequacy of the allotment. What nutritional levels are achieved by poor families of varying size, and in various geographic regions with the current, nationally-uniform food stamp allowance is, as yet, an unanswered question.

stamp allotment.) In addition to the relative effect, it is likely that absolute income limitations would force the lower income family to change its food purchase patterns since, even with the $55 subsidy from food stamps, it would have to spend $50 more per month to maintain previous food purchase patterns. Of course, the complexities of the distribution effects reach out farther than changes in food prices.

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Social Costs Caused by Errors in Agricultural Production Forecasts

J. Bruce Bullock

Considerable concern has been voiced recently about inaccurate forecasts of agricultural production by the Statistical Reporting Service (SRS), particularly with respect to livestock numbers. SRS forecasts are a major (but not the only) source of information and thus affect allocative decisions in U.S. agriculture. The accuracy of SRS forecasts would appear to be a valid area of concern. Increased accuracy of SRS estimates would require additional expenditures. Several questions need to be answered prior to committing funds for this purpose. What is the nature and magnitude of social costs generated by SRS forecast errors? Do all forecast errors generate social costs? Is the magnitude of these social costs dependent on the size of the forecast error?

The purpose of this note is to develop models that help provide answers to these questions. An inventory adjustment model is used to evaluate social costs generated by inventory changes in response to a SRS forecast. A production adjustment model is used to examine the social costs resulting from production changes generated by a forecast.[1] These models ignore other sources of forecast information and the updating of SRS reports. Thus, they overstate the social costs of SRS forecast errors, but the models illustrate the nature of such social costs. The assumptions of the models are not intended to reflect reality. Rather, they define the conditions necessary to isolate the impact of forecast errors while restricting the analysis to two-dimensional graphs. Linear supply and demand curves are used for simplicity. However, the conclusions are not limited to linear functions.

Inventory Adjustment Model

The inventory adjustment model examines a two-time-period situation where production cannot be altered in response to output forecasts. The source of social cost is an erroneous SRS forecast of period two production. Harvest occurs at the beginning of each period. Consumption is spread over both time periods. The forecast is released prior to period two harvest, but after all period two production decisions have been made. Total supplies available for consumption in period one are known with certainty at the time the SRS forecast is released. Information about demand curves in the respective periods and about storage costs is also known with certainty at the time of the forecast.

Inventory holders are assumed to make inventory decisions at the time the SRS forecast is released. Consumption for the remainder of period one and carry-over into period two are determined by the following condition, $P_1 = \hat{P}_2 - C$, where P_1 is the price in period one, $\hat{P}_2$ is the expected price in period two, and C is the per unit storage cost.

The inventory adjustment model is represented in figure 1. Market conditions are depicted at the time the forecast of period two production is made; D_1 and D_2 represent the demand curves in the respective time periods; S_1 represents the total supplies (including stocks) available in period one; Q_2 is the true production that will occur in period two, i.e., the production level that SRS is trying to forecast; ED_1 and ED_2 represent the excess demand curves in the respective periods. (The reader not familiar with the derivation and interpretation of excess demand curves should see Bressler and King, pp. 206–9.)

The demand curve for storage services is RA. It is found by subtracting ED_1 from ED_2 at alternative levels of storage; RA shows the prices that consumers are willing to pay for alternative quantities of storage services. The area under RA is a measure of the total social value of alternative levels of storage.

The marginal social costs of using the storage inputs to store alternative quantities of the product from period one to period two is represented by CJ. In addition, CJ can contain a discount factor to account for time preferences of consumers. The area under CJ represents the total social costs of alternative levels of storage.

With perfect information (i.e., an accurate forecast) the optimal level of storage is defined by the intersection of CJ and RA. This equates the marginal social value of storage services with the marginal social cost of storage services. Thus, with a perfect forecast, OH units would be stored from period one to period two and $OM = (OS_1 - OH)$ units would be consumed in period one at a price of

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[1] These models examine the same situations considered by Hayami and Peterson. However, the Hayami-Peterson theoretical framework is incomplete. Thus, they have not appropriately identified the social costs due to forecast errors.

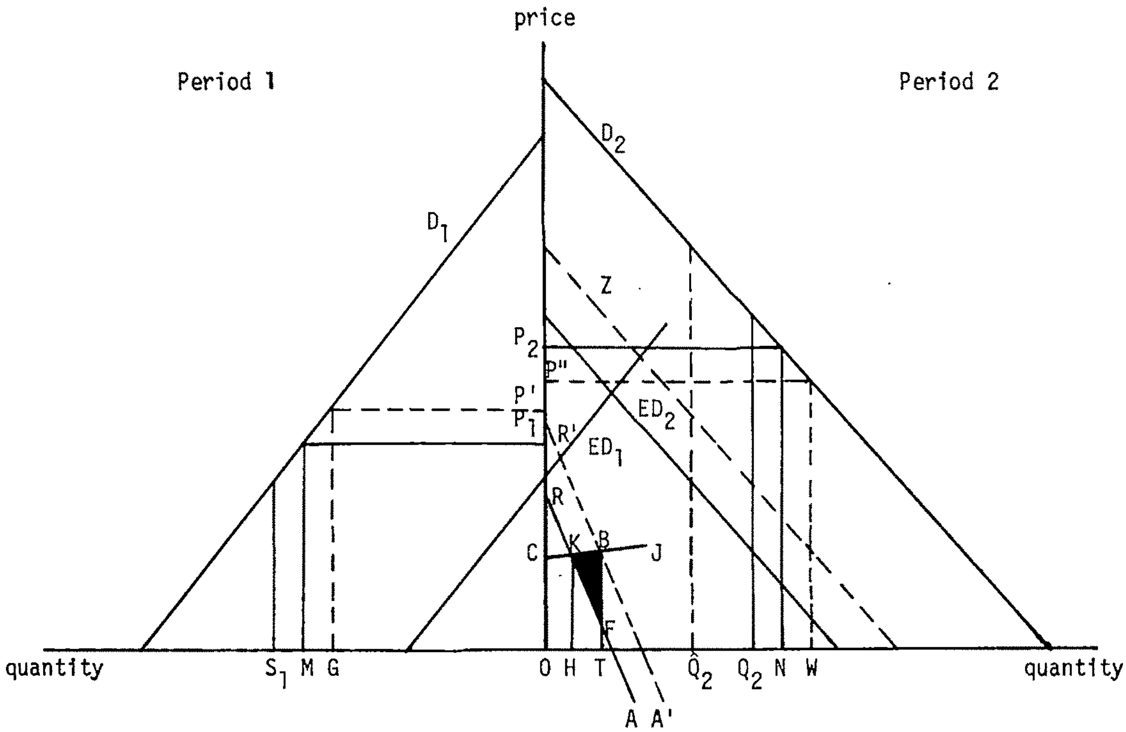

Figure 1. Inventory adjustment model, storage from period one to period two with perfect forecast

P_1. A total of $ON = (Q_2 + OH)$ units would be consumed in period two at a price of P_2. At equilibrium, the marginal value of storage $(P_2 - P_1)$ is equal to the marginal cost of storage (HK).

If SRS underforecasts the true production (i.e., $\hat{Q}_2 < Q_2$) and if the market uses $\hat{Q}_2$ as its estimate of period two production, then Z becomes the excess demand curve for period two. The excess demand curve for period one (ED_1) remains unchanged. The underforecast causes the demand for storage to shift to $R'A'$. Consequently, OT units would be stored from period one to period two, and OG units would be consumed in period one at price P'; $OW = (Q_2 + OT)$ units would be consumed in period two at price P''. The underforecast leads to more than the optimal amount of storage, since $(P'' - P')$ is less than the marginal costs of storage, TB.

The amount of excess storage generated by the erroneous forecast is measured by HT. The social value of this additional storage, $HKFT$, is less than the total social cost of the additional storage $HKBT$. Thus, the net social cost of the underforecast is measured by the triangle KBF.

The effect of underestimating period two production is to shift RA to the right resulting in more storage than is socially optimal. The magnitude of the social cost caused by an underforecast increases as the magnitude of the error increases. The social cost triangle is bounded above by CJ and below by RA; K is one point on all such triangles. The social cost triangle is bounded on the right by a vertical line drawn at the quantity stored as a result of the erroneous forecast.

Overforecasts of period two production cause RA to shift to the left and result in less storage than is socially optimal. The social cost triangle for an overforecast lies to the left of point K and is bounded by RA from above and CJ from below. The social cost of an overestimate of period two production has an upper limit of KCR. This limit is reached when the magnitude of the overforecast is large enough to shift the demand for storage (RA) downward sufficiently so that it no longer intersects CJ. Beyond this point, the social cost of forecast errors remain at KCR regardless of the magnitude of the overforecast.

This leads to two important observations. In those cases where actual supply and demand conditions are such that the intersection of CJ and RA occurs at very low levels of storage (i.e., there would be very little storage even with a perfect forecast), the social cost of an overforecast is small and will reach the upper limit at very low levels of overforecasting errors. Secondly, the social cost of an overforecast is zero regardless of the magnitude of the overforecast in those situations where there would be no storage from period one to period two given a perfect forecast (i.e., CJ and RA do not intersect). In situations represented by figure 1, all forecast errors generate social costs and there are direct social benefits from reducing the average level of SRS forecasting error.

Figure 2 illustrates the social cost of un-

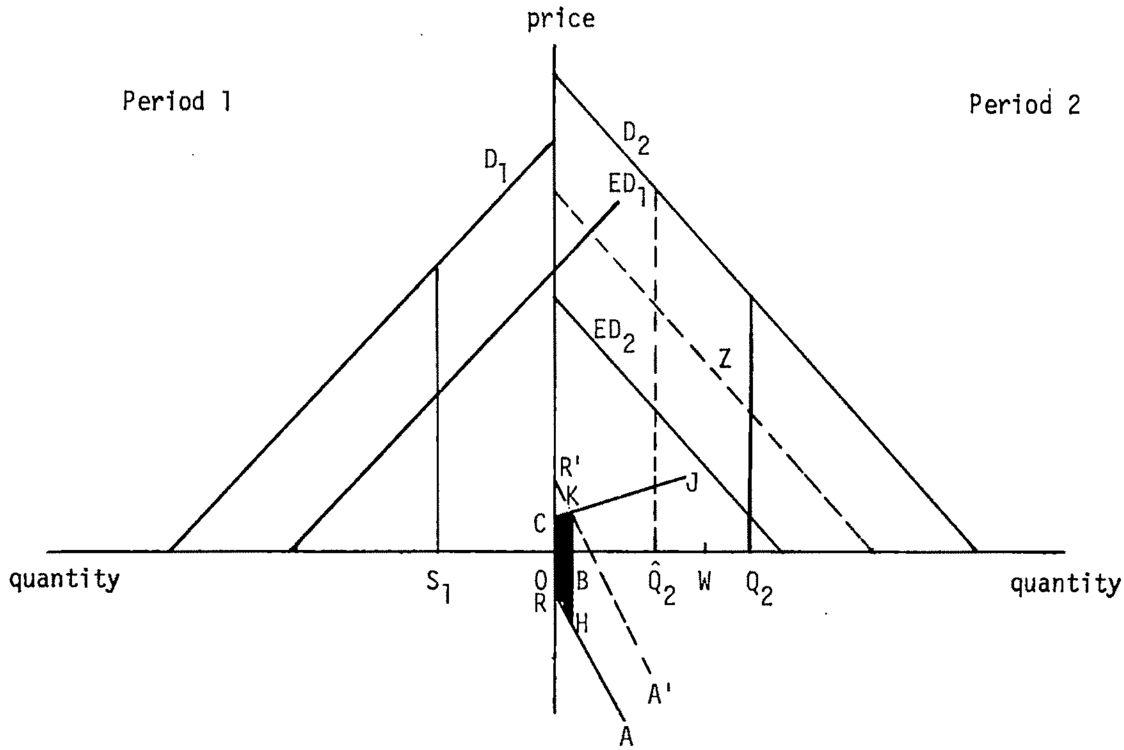

Figure 2. Inventory adjustment model, no storage from period one to period two with perfect forecast

derforecasts in situations where no storage would take place with a perfect forecast. The curves are labeled the same as in figure 1. With an accurate forecast, *RA* and *CJ* do not intersect leading to zero storage. The effect of an underforecast of period two production, $\hat{Q}_2$, is to shift *RA* upward. An error of this magnitude shifts *RA* to *R'A'* and leads to storage of *OB* units. This generates social costs measured by the trapezoid *CKHR* which is the sum of the social cost of storage *OCKB* and the negative social value of the storage *OBHR*. However, underforecast errors will generate social costs only when *RA* is shifted upward sufficiently to cause it to intersect *CJ*. Underforecasts between Q_2 and *W* will not generate social costs in the situation depicted by figure 2. The point *W* is the underforecast that would shift *RA'* upward to just intersect *CJ* at point *C*. Underforecasts between *W* and *O* will generate social costs as illustrated by *CKRH*. All forecasts greater than or equal to *W* will generate zero social costs. Thus, in situations represented by figure 2 there will be no direct social benefits from reducing the average level of SRS forecasting error unless the probability of a forecast being less than or equal to *W* is reduced.

The models developed above provide the following observations about the effects of forecast errors in cases where the inventory adjustment model is applicable. Not all forecast errors generate social costs. In many cases, the magnitude of the social cost of an erroneous forecast is independent of the magnitude of the forecast error beyond some minimum level of error. The social cost of a given forecast error is unique to the set of supply and demand conditions existing at the time of the forecast. Thus, it is not possible to categorically state that an X% forecast error will generate Y dollars of social costs. In general, the social cost of an X% overforecast is not symmetrical with the social cost of an X% underforecast. Thus the benefits to improved accuracy of SRS forecasts depend on how the frequency distribution of forecasts is changed.

Production Adjustment Model

This model applies to situations where producers have an opportunity to modify output in response to the SRS production forecast. The forecast is released sometime between the beginning of the normal production period and its scheduled termination. A single period where consumption equals production is considered. Forecast errors generate social costs through misallocation of resources in the production process. The magnitude of these social costs is determined by the prior production plans of producers and their subsequent modification of output in response to the SRS forecast.

The production adjustment model is depicted in figure 3; *DD* represents the demand curve for the product anticipated by producers; *SS* represents the supply curve at the beginning of the production

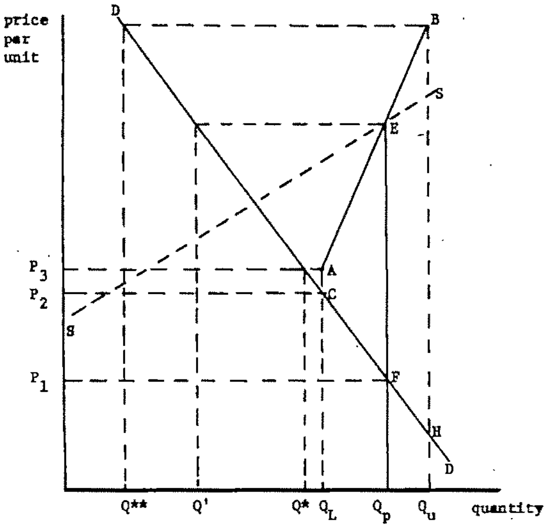

Figure 3. Production adjustment model with Q_L equal the socially optimal level of output

period. The initial intention of producers is to produce output Q_p. The necessary inputs have been committed to achieve this level of output; AB is the supply response curve of producers at the time the SRS forecast is released. Once the normal production process has begun, the ability (willingness) of producers to adjust output is restricted. At the time of the SRS forecast, Q_u is the maximum output that can be obtained by the designated harvest (slaughter) date and Q_L is the minimum production that will be placed on the market. The supply response curve becomes steeper and the distance between Q_u and Q_L diminishes as the length of time remaining in the production period is reduced. The slope of AB and the range between Q_u and Q_L also depend on the product in question.

Social costs measured by the area $CAEF$ are generated because of prior production decisions unless production plans are changed. (See Wallace for a discussion of the concept of social costs and socially optimal levels of production.) The social value (cost) of an SRS forecast arises from the reduction (expansion) of the area $CAEF$ due to modifications of output in response to the SRS forecast.

Figure 3 represents a situation where the lower bound on output is also the socially optimal level of output, given prior production decisions. In this situation, any forecast (regardless of its accuracy) that leads to a reduction in output up to Q_L will have positive social value. For example, if SRS accurately predicts Q_p as the level of output forthcoming, producers would anticipate a price of P_1 and reduce output to Q_L.[2] The price at the end of the period would be P_2. The social cost due to prior production plans has been eliminated as a result of the forecast. The social value of the forecast is measured by the area $CAEF$.

If SRS incorrectly predicted Q^* as the level of forthcoming output, producers would anticipate price P_3 and reduce output to Q_L. This erroneous forecast has the same social value as a perfect forecast, namely $CAEF$. Moreover, any forecast, F, such that $F > Q^*$ also has a positive social value equal to $CAEF$.

Any forecast in the interval $Q' < F < Q^*$ has a positive social value since the effect of any of these forecasts is to reduce output. However, these forecasts result in less than the maximum output reduction. Consequently, their social value is some portion of the area $CAEF$. A forecast $F = Q'$ has no effect on output level and thus has zero social cost.

Only those forecasts that cause an expansion in output have negative social value. Forecasts $0 \leq F \leq Q^{**}$ cause the maximum expansion of output. The social cost of any forecast in this range is measured by the area $FEBH$. Forecasts $Q^{**} < F < Q'$ also have negative social benefits measured by portions of $FEBH$ depending on the amount of output expansion generated.

Thus, in situations represented by figure 3, reduction of the average error of SRS forecasts will be certain to have direct social benefits only if the probability of obtaining forecasts less than or equal to Q' is reduced while at the same time changing the distribution of forecasts greater than Q' in such a way that the expected value of social benefits from forecasts $> Q'$ is not reduced. It is possible that a reduction in the average forecast error could also reduce the expected social value of the forecast.

Similar results are obtained from a graphical analysis where the demand curve lies to the right of the supply response curve AB. In this case, Q_u is the socially optimal level of output and any forecast (regardless of its accuracy) that leads to expanded output up to Q_u has positive social value.

Figure 4 illustrates the situation where the demand curve intersects AB, and thus the socially optimal level of output lies between Q_u and Q_L.[3] Forecasts $F \leq Q'$ cause output to be reduced to the lower bound Q_L. This generates social benefits equal to $GEF - GAC$. If $(Q_e - Q_L) > (Q_p - Q_e)$, the area GAC exceeds the area GEF and each of these erroneous forecasts generates social costs. However, these forecasts have positive social value if $(Q_e - Q_L) < (Q_p - Q_e)$ and have zero social cost if $(Q_e - Q_L) = (Q_p - Q_e)$.

[2] The measurement of forecast errors is thus impossible in cases where the production adjustment model is applicable. Prior production plans are not observable. In the above example, the true forecast error is zero. However, there is an observed forecast error of O_p (forecasted production) minus Q_L (observed production). If SRS had incorrectly arrived at Q_L as its estimate of Q_p, then the observed forecast error would be zero even though an incorrect estimate of Q_p had been made. There appears to be no definite relationship between actual and observed forecast errors.

[3] A special case of this situation is where DD and AB intersect at Q_p. In this case, all forecast errors regardless of their magnitude generate social costs.

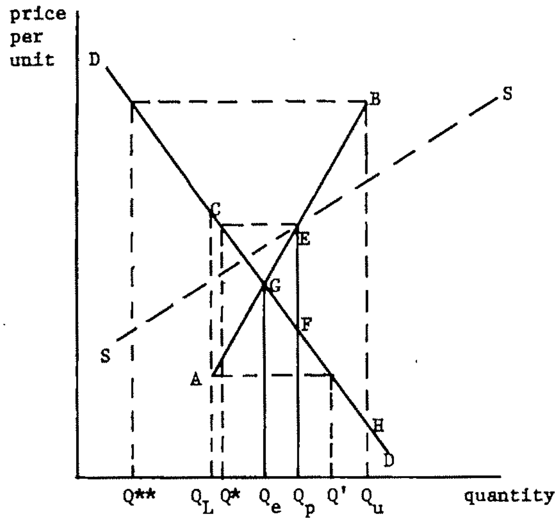

Figure 4. Production adjustment model with $Q_L < Q_e < Q_u$

Any forecast in the interval $Q_e < F < Q'$ has a social value of GEF minus some portion of GAC. The social value of some of the forecast in this interval is negative if $GAC > GEF$. A perfect forecast, $F = Q_p$ is contained in the interval $Q_e < F < Q'$. Thus, it is possible for a perfect forecast to have negative social value. The social value of forecasts in the interval $Q_e < F < Q'$ increases as F approaches Q_e. If $F = Q_e$, the social value of the forecast is maximum at GEF. Therefore, in situations represented by figure 4, if $Q_e \neq Q_p$, there exists a set of erroneous forecasts in the neighborhood of Q_e which have higher social value than a perfect forecast.

If $F = Q^*$, the forecast has zero social value since output is left unchanged. If $Q^* < F < Q_e$, the social value of the forecast is some portion of GEF. Forecasts in the interval $Q^{**} < F < Q^*$ cause output to be expanded and generate social costs measured by some portion of the area $EFHB$. All forecasts $F \leq Q^{**}$ have social costs equal to the area $EFHB$.

No general statement can be made about the direct social benefits from reducing the average level of SRS forecast errors in situations represented by figure 4. Many possibilities exist. It is clear, however, that the relative frequency of forecasts falling in certain intervals is the important determinant of the possible benefits, not just the average error. Reducing the average error is no guarantee that the expected social value of the forecast will be increased.

The models illustrated by figures 3 and 4 provide the following observations about the effects of SRS forecast errors in situations where the production adjustment model is applicable. Not all forecast errors generate social costs. In fact, there are many situations where even erroneous forecasts generate positive social value. In many situations only very large forecast errors generate negative social benefits. The magnitude of social costs (or benefits as the case may be) are often independent of the magnitude of the forecast error over a wide range of forecast errors. In some cases, erroneous forecasts have higher social benefits than accurate forecasts. In general, the social cost of a *X%* overforecast is not symmetrical with a X% underforecast. Thus, the benefits to improved accuracy of SRS forecasts depend on how the frequency distribution of forecasts is changed.

Conclusions

The models developed above illustrate the nature of social costs generated by production forecast errors in selected situations where the only source of imperfect information is the erroneous forecast. In general, accurate forecasts are preferable to inaccurate forecasts. However, large forecast errors are not sufficient grounds to argue for additional expenditures to improve the accuracy of SRS forecasts. In situations represented by the models, the sheer magnitude of the forecast error need not be of concern. The impact of an erroneous forecast depends on the set of supply and demand conditions existing at the time of the forecast. Moreover, reducing the average forecast error will not always generate social benefits. The key variable is how the frequency of forecasts has been changed in the process.

This note has not attempted to estimate the social payoff to improving the accuracy of SRS forecasts. This will require first, projections of the probability distribution of possible supply and demand conditions at the time of the forecast and secondly, estimates of the conditional frequency distributions of forecast errors (given the existing supply and demand situation) prior to and after the modification of SRS forecasting procedures. The expected social value of SRS forecasts prior to modifications could be compared with the expected value after modifications to obtain an estimate of the social benefits of the modifications. This does not appear to be a promising area of research, however, due to the complexities of obtaining the necessary estimates in a world characterized by many sources of uncertainty other than SRS forecast errors.

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Futures Prices in Supply Analysis

Bruce L. Gardner

Empirical work on agricultural supply functions typically makes use of product prices from past time periods. This approach has the important advantage that it avoids the problems created by the simultaneous determination of supply and demand, since past prices are predetermined. But the approach has the important drawback that theory does not reveal exactly which past prices to use. The simplest procedure, use of last year's price, assumes farmers to be unduly naive in the formation of expectations. The more sophisticated lagged-price procedures following the work of Nerlove create econometric problems (Brandow, Nerlove 1958c, Griliches). Some are also liable to the charge of "theoretical ad-hockery" (Griliches, p. 42ff).

As an alternative approach to estimating supply elasticity, this paper is an attempt to exploit the theoretically well-grounded hypothesis that the price of a futures contract for next year's crop reflects the market's estimate of next year's cash price.[1] Since the appropriate price for supply analysis is the price expected by producers at the time when production decisions are being made, a futures price at this time is a good candidate for a directly observable measure of product price in supply analysis.

In the context of crop supply, there are several problems to be faced in the use of futures prices. First, "the market's" estimate as given by a futures price reflects the expectations of nonfarm speculators as well as crop producers, and it reflects directly the expectations only of those crop producers who themselves make futures transactions. Second, there is the issue of which futures contract is most appropriate. Third, at what date should the futures price be observed?

With respect to the first issue, the use of a futures price can be justified by the hypothesis of rational expectations as developed by John Muth. Under rational expectations, there is no reason for farmers to have different price expectations from futures speculators, nor for farmers who make no futures transactions to have expectations different from those who do. If the price expectations of those out of the futures market differ from the futures price, there is great incentive for them to enter. Thus, those out of the market likely have price expectations similar to the market price of futures.[2]

The second issue should cause no serious problem so long as the futures contract pertains to the new crop. Of course, even old-crop cash prices are influenced by expectations concerning the new crop. But the cash-futures basis changes from year to year and secularly as the cost of storage (which includes interest) changes. The present analysis uses the first futures price after the crop is in.

The third problem is most difficult because it is not clear exactly when the production decision is made. There may not be any preharvest date at which a farmer can be said to have made irrevocably his decision about planned output. Even after the crop is planted, planned output can be revised and actions taken accordingly in fertilization, pest control, and other practices, such as plowing under a crop or using it for forage. However, the main production decisions are the choices of acreage and techniques to follow in planting. This suggests taking as the expected price the futures price in the period immediately preceding the planting season.

When Nerlove (1956) introduced into agricultural supply analysis the fruitful innovation of the lagged dependent variable as an independent variable, he justified the procedure by an adaptive expectations model in which expected price is a distributed lag function of past prices. But as he notes (1956, p. 502n.) the resulting estimating equation is identical to that generated from a partial adjustment model in which expected price is simply last year's price.[3] The use of a futures price avoids this ambiguity. Under the maintained hypothesis that the futures

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[1] The extent to which futures prices are unbiased point estimates of subsequent cash prices has been explored in a large theoretical and empirical literature, e.g., Dow, Working, Tomek and Gray, Telser. It seems fair to say that this literature does not indicate that futures prices for the major agricultural crops are biased. Telser concludes from his empirical analysis that, in fact, "the futures price can be considered as an unbiased prediction of the subsequent spot price" (p. 174).

[2] Hawtrey discusses the complications caused by people who have vague expectations or no expectations at all. He concludes that "the introduction of the expected price in any form, far from being simplification, is an additional complication" (p. 205), the implication being that we would be better off without the concept of "the market's" expected price. Nonetheless, in treating market supply, some such concept is necessary. If it turns out that many do not form expectations and act randomly or like robots, then the data should reveal it via insignificant response to "expected price."

[3] For a lucid explanation and comparison of adaptive expectations and partial adjustment models, see Nerlove (1958a) or Griliches (pp. 16–17).

price is the expected price, the coefficient of the lagged dependent variable arises from partial adjustment only. This fact is useful econometrically because the partial adjustment approach, unlike the adaptive expectations model, does not induce serial correlation when the supply equation errors are serially uncorrelated (Griliches, p. 17).

Although the use of a futures price in supply analysis seems basically plausible, it may be questioned for a number of reasons. Therefore, an appeal to concrete empirical problems is necessary to judge whether futures prices are useful in supply analysis. The remainder of this paper applies futures prices to the analysis of supply of soybeans (1950–74) and cotton (1911–33). These particular cases are chosen because there are good existing empirical studies with which to compare the results.

Supply of Soybeans, 1950–74

The futures price used for the analysis of soybean supply is the price of a January contract on the Chicago Board of Trade. The January contract yields a completely new-crop price. Because it is not certain at exactly what date the futures price should be observed and to help average out short-term price fluctuations, an average of futures-price observations is advantageous. However, to economize in data collecting, a simple average of only two prices is used. These are the closing price of the January position on the last Friday of the preceding April and on the last Friday of the preceding May.

The economic model used follows that of Heady and Rao. They explain soybean production as a function of the lagged (one year) price of soybeans, the lagged price of corn, lagged production, and a dummy variable denoting the presence of feed grain and acreage allotment programs for corn, wheat, and cotton. Table 1 shows estimated regression coefficients for a similar model on 1950–1974 data which allows comparison between lagged price and futures price results.

Equation (1) uses futures prices for soybeans and corn. For purposes of comparison, equation (2) presents lagged-price regressions. The directly calculated (short-run) elasticity of supply computed from equations (1) and (2) increases from 0.45 to 0.73 when futures prices replace lagged prices. The futures price also yields a lower standard error than lagged price.[4]

None of the equations contains an explicit policy variable. A couple of variables following Houck and Ryan were tried but were insignificant. The lagged-price equation substitutes the support price for lagged price in the one year (1961) when the support price was higher. The substitution makes no notable difference.

If adaptive expectations were the sole rationale for using the lagged dependent variable, then there would be no reason to include X_{t-1} in equation (1). However, the partial adjustment model predicts a smaller short-run than long-run supply response even when the expected price is included. Equation (3) drops X_{t-1}. The elasticity of supply with respect to futures price in equation (3) is less than even the short-run elasticity from equation (1). This result is consistent with the hypothesis that partial adjustment is important and that therefore X_{t-1} should be included along with the futures price. However, it is also consistent with Brandow's argument that including X_{t-1} may bias the estimated elasticity of supply upwards.

[4] Because corn and soybeans prices are highly correlated, it is possible to improve t-values on prices by using the ratio of soybeans to corn price as independent variables instead of the two prices separately. The ratio specification is used in Heady and Rao. On the 1950–74 data, the ratio of lagged prices yields a coefficient (with "t") of 249 (2.5), implying a short-run elasticity of supply of 0.69. The price ratio specification for futures prices yields a coefficient of 302 (3.6), implying a short-run supply elasticity of 0.83.

Table 1. Estimated Soybean Supply Functions, U.S., 1950–74

	Regression Coefficients (with t-ratios)[a]							Elasticity of Supply	
Equation	PS^*_t	PS_{t-1}	PC^*_t	PC_{t-1}	X_{t-1}	t	$\bar{R}^2$	SR	LR
(1)	219		−438		0.44	18.2	0.957	0.73	1.30
	(2.5)		(2.1)		(1.7)	(1.1)			
(2)		136		−315	0.43	19.6	0.948	0.45	0.79
		(1.3)		(1.3)	(1.5)	(1.1)			
(3)	184		−241			45.2	0.953	0.61	
	(2.1)		(1.3)			(9.3)			

[a] The dependent variable is U.S. soybean production in millions of bushels; PS_{t-1} and PC_{t-1} are the lagged season-average prices of corn and soybeans; PS^*_t and PC^*_t are the futures prices of soybeans and corn; PS^*_t is the price of January soybeans in April–May as discussed in the text; PC^*_t is the December corn futures price on the last Friday in April; X_{t-1} is the dependent variable lagged one year; t is time in years, 1950 = 1, 1951 = 2, etc.

Soybean Acreage Response

Although Heady and Rao explain output, it is more usual for agricultural supply analysis to explain acreage. This approach yields a factor-use equation and not a supply equation, and the "elasticity of supply" obtained is not an elasticity of supply in the usual sense. Nonetheless, acreage response functions are useful as an indicator of output intentions.[5] They are also suitable for the use of futures prices, especially when the futures prices are observed at planting time. Table 2 presents estimates of acreage response functions for soybeans using lagged prices and futures prices. Again, the futures price equation yields a larger point estimate of response elasticity than the lagged-price equation, although the apparent difference is not significant for the short-run elasticity.

Cotton Acreage Response, 1911–33

The cotton futures price used is the closing price of a December contract at the end of March.[6] The model is that of Nerlove (1958b) as modified by Tomek to make use of the data of Walsh. It does not include the price of an alternative crop, as the soybean model did, but deflates the cotton price by the U.S. Department of Agriculture index of prices paid by farmers. The use of the 1911–33 period is an interesting test case in that the use of futures markets by farmers was less widespread than in recent years. This puts the rational expectations hypothesis as a justification for using futures prices to a more severe test.

Regression coefficients for the model are presented in table 3. The coefficients and implied supply elasticities using the futures price are quite close to those obtained from the same model using the lagged price. The futures price and the lagged cash price seem to be good substitutes. In the cotton case, dropping the lagged dependent variable in equation (9) makes no difference in estimated response elasticity.

Conclusions

The use of futures prices seems a promising tool in supply analysis. In the soybeans and cotton equations, futures prices gave reasonable results and performed at least as well as Nerlovian lagged-price, lagged dependent variable specifications.

Futures prices have been applied in this paper only to crop supply, although the same basic idea could just as well be applied to livestock. Indeed, futures prices may be even more helpful in modeling the complex relationships of the livestock sector. For example, cow slaughter and placements on feed depend on near-term relative to longer-term price expectations. Futures prices for different positions give an observable indicator of near-term relative to far-term differences in price expectations.[7]

[5] A rigorous comparison of supply elasticity with acreage response elasticity can be made in the context of the model used in Floyd and in Richard Muth. Comparing Floyd's equation (7) for factor-use elasticity to Muth's equation (19) for supply elasticity, we have elasticity of acreage w.r.t. product price $= [e_a(e_b + \sigma)]/[\sigma + S_b e_a + S_a e_b]$ and elasticity of output w.r.t. product price $= [e_a e_b + \sigma(S_a e_a + S_b e_b)]/[\sigma + S_b e_a + S_a e_b]$, where S_a is the relative share of acreage in total cost, S_b is the relative share of all other inputs taken together, e_a and e_b are the own-price elasticities of supply of land and other inputs, respectively, and σ is the elasticity of substitution in production between land and other inputs. The elasticity of acreage with respect to product price will give an unbiased estimate of supply elasticity if land and other inputs are used in fixed proportions ($\sigma = 0$) or if the elasticity of supply of land is equal to that of all other inputs taken together ($e_a = e_b$). However, when $\sigma \neq 0$ and $e_a < e_b$, which is the likely real-world case, the acreage-response elasticity understates supply elasticity. The size of the bias depends on the magnitude of the parameters. To take an arbitrary example, if $\sigma = 0.5$, $e_a = 0.2$, $e_b = 1.0$, $S_a = 0.25$ and $S_b = 0.75$, the elasticity of product supply is 0.67 while the elasticity of acreage with respect to product price is 0.33.

[6] Two prices were averaged in order to smooth out single-day random price movements, the closing prices on Wednesday and Friday. These prices were chosen simply for convenience; the prices were taken from microfilms of the *New York Times*, and the Wednesday and Friday closing prices are both reported in Friday's paper. As it turns out, the correlation coefficient between the Wednesday and Friday price is 0.9987 in this sample.

[7] Leuthold (1974, 1975) finds that livestock futures prices are

Table 2. Soybean Acreage Response Functions, U.S., 1950–74

	Regression Coefficients (with t-ratios)[a]							Elasticity of Acreage	
Equation	PS^*_t	PS_{t-1}	PC^*_t	PC_{t-1}	A_{t-1}	t	$\overline{R}^2$	SR	LR
(4)	7.2		−10.2		0.55	0.59	0.981	0.61	1.36
	(3.6)		(2.0)		(2.4)	(1.3)			
(5)		6.7		−10.1	0.46	0.67	0.977	0.56	1.04
		(2.8)		(1.8)	(1.9)	(1.3)			
(6)	5.3		−1.6			1.70	0.977	0.45	
	(2.6)		(0.4)			(15.1)			

[a] The variables are the same as in table 1 except that the dependent variable is millions of acres of soybeans planted; A_{t-1} is the lagged dependent variable.

Table 3. Cotton Acreage Response Functions, U.S., 1911–33.

Equation	Regression Coefficients (with t-ratios)[a]				$\overline{R^2}$	Elasticity of Acreage	
	P_{t-1}	P^*_t	A_{t-1}	D		SR	LR
(7)	0.76		0.03	9.5	0.91	0.24	0.26
	(7.5)		(0.2)	(7.5)			
(8)		0.74	0.15	8.1	0.86	0.23	0.28
		(5.7)	(1.0)	(5.3)			
(9)		0.75		9.3	0.85	0.23	
		(5.8)		(10.7)			

[a] The dependent variable is millions of cotton acres in cultivation July 1; P_{t-1} is the previous season average price received by farmers. P^*_t is the price of December cotton futures at the end of March; P_{t-1} and P^*_t are deflated by the index of prices paid by farmers; D is zero in 1910–24 and 1 in 1925–33; (for a discussion of this variable, see Tomek [p. 109]); P_{t-1} and A are from Walsh (p. 368).

Futures prices can be valuable as an adjunct to and as a vehicle for evaluating lagged-price, lagged dependent variable models. Using futures price removes the main justification originally given by Nerlove for introducing the lagged dependent variable. The fact that substituting futures for lagged prices does not have a large impact on the coefficient of X_{t-1}—compare equations (1) and (2), (4) and (5), (7) and (8)—suggests that X_{t-1} is capturing something other than adaptive expectations of price. Nerlove himself indicates (1958c, p. 724n.) that he subsequently gave increased emphasis to the partial adjustment interpretation of the lagged dependent variable model. Nonetheless, the lack of evidence for an adaptive expectations effect being captured in X_{t-1} increases one's feeling that X_{t-1} may be picking up the effects of left out variables. More detailed work addressed specifically to such econometric problems would be necessary to draw any conclusions in this area.

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poor estimates and systematically underestimate subsequent cash prices. This does not bode well for the use of futures prices in livestock supply studies. Nonetheless, the estimate, though poor, may still be "the market's" estimate, and the downward bias may indicate that expected prices have tended to be too low (instead of indicating that futures prices have been below expected prices).

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Estimating Irrigation Response from Data on Unirrigated Crops

R. W. Palmer-Jones

In a paper in this *Journal*, Parvin suggests that, provided two conditions are met, the response of a crop to irrigation can be approximated from historical data on the unirrigated crop by assuming that irrigation will result in an increase in yield equal to the difference between actual yield and yield had "ideal" weather obtained. Ideal weather, as used by Parvin, is that which gave the maximum positive difference between estimated yield for "average" weather in a year and actual yield in that year.[1] The assumptions are that ideal weather occurred once during the data series and that irrigation has the same effect on yield as ideal weather. It is probably necessary to add a third assumption, namely, that no interaction exists between technological advance and response to weather and/or irrigation.

The second assumption is not valid in at least one case, and there are very good physiological and climatic reasons for supposing that the assumption will not hold in a wide range of circumstances. Parvin and Nelson make the point that all yield variability will not be eliminated by irrigation and the bias from using the assumption will be upward. Treating irrigation as rainfall will result in bias, but the direction will depend on the crop and environment.

Furthermore, while it enables use to be made of historical yield data, the method allows the evaluation of only those irrigation system operating policies—rules about how much water to apply to each area at each time with a given set of irrigation facilities—which enable maximum yields to be obtained. These policies, since they disregard costs, cannot be presumed always to be economically optimal. Consequently, the set of irrigation system operating policies and the system capacities required to implement them, which can be evaluated by the method, may not contain the economic optimum.

The assumption in question—that the effect of irrigation is the same as ideal weather—is similar to another assumption that appears quite frequently, explicitly or implicitly, namely that irrigation has the same effect as rainfall (Burt and Stauber, Carruthers and Donaldson). "Ideal" weather occurs in the year when the distribution of rainfall gives maximum yields; hence, if irrigation simulates this pattern, the same yield will result. This assumption is open to similar objections. Irrigation affects mainly soil moisture, while rainfall will be correlated with a wide range of other environmental variables such as temperature, humidity, radiation, and wind speed, all of which are known to affect plant growth and yield. In fact, irrigation will tend to be applied in conditions where these variables are at their opposite values to those prevailing in rainy conditions. For example, if temperatures under rainfed conditions are limiting plant growth, irrigation will tend to do better than the best rainfed yields, because in years when irrigation is necessary, temperatures in the absence of rainfall will tend to be higher. The opposite circumstances contain perhaps more dangers. Thus, if temperatures or humidities under rainfed conditions are at the upper limit of the response curve, then the higher temperatures and lower humidities associated with dry spells will limit yield response to irrigation to a lower level than may be expected with "ideal" weather. This latter situation is especially likely in the arid tropics and subtropics where much is hoped for from irrigation, but it is perhaps less probable in temperate regions and the humid tropics.

To be fair to many of the workers who have assumed that irrigation is equivalent to ideal weather, they have usually, but not always, made the assumption explicit.[2] Even so, it is worth emphasizing the importance of interactions among soil moisture, plant growth, and atmospheric environmental factors in determining growth and yield. Two examples from a study of the possibilities of

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[1] Ideal weather is defined by Parvin as those conditions which will result in maximum yields for the crops grown. As a result of the conclusions of this paper, one would also have to specify whether the crop was irrigated, since conditions for the area and time of year which give maximum yields under rainfed conditions might not give maximum yields under irrigated conditions.

[2] For example, Asopa, Guise, and Swanson make use of the methodology developed by Burt and Stauber in which rainfall and irrigation are aggregated, but they state neither the assumption, nor whether the data used for estimation came from irrigated or unirrigated yield data. If the latter, then multicollinearity between independent variables might be a significant source of error in estimated regression coefficients. For this reason, even the complex regression equation used, following Doll, and Burt and Stauber, might give biased results unless estimated using irrigation data.

irrigating tea in Malawi are given where estimates of response to irrigation using empirical yield-natural weather data have given highly misleading predictions. A somewhat more long-winded procedure to estimate response to irrigation from natural weather-yield relationships, which appears to be an improvement, is likely to have problems of statistical estimation.

The yield of tea may be related to the level of incoming energy, measured as evapo-transpiration, when soil moisture is not limiting (Laycock). Soil moisture was taken to be limiting whenever estimated evapo-transpiration in any ten-day period was less than rainfall in that period; in this case, the level of useable energy was put at the amount of rainfall. The annual sum (Etw) of whichever was less in each ten-day period, rainfall or evapo-transpiration, was correlated with annual yields and a highly significant coefficient found.[3] Laycock went on to suggest that irrigation would have the same effect as rainfall and that the effect of irrigation on yield might be predicted from his regression equations. An 80% increase in annual yield was indicated. Using later data, Shaxson found a similar result. Carruthers and Donaldson report a similar function for tea in Bangladesh.

Experience from irrigation experiments in Malawi, however, has failed to confirm the "Etw" hypothesis (Palmer-Jones). Yields from irrigated tea have nowhere in Malawi shown more than a 40% increase in annual yield, and it has been shown elsewhere (Palmer-Jones, p. 270) that the differences in yields between different irrigation treatments (including no irrigation) in different years is better explained by a partial regression of yield on Etw due to natural weather (Etwn) and on Etw due to irrigation, treated as a residual (Etwi), than by a regression of yield on total Etw. The two regressions gave determination coefficients (R^2) equal to 0.80 and 0.58, respectively.[4]

The regression coefficient of Etwi was less than one-sixth of that of Etwn implying that irrigation was considerably less effective than rainfall at increasing yields. This finding clearly illustrates the dangers of relying on natural weather-yield relationships for estimates of irrigation response.

The effect of irrigation on yields, as pointed out, is through its effects on soil moisture. Recently a study related yields in a number of years of unirrigated tea in Malawi to estimated soil moisture conditions at various times and suggested that irrigation response might be predicted from these measures (Willatt). Lal used a similar procedure in another place. The problem with this approach is the association between the estimated soil moisture conditions and the set of values of other environmental variables which will contribute to the determination of growth and yield. Thus, in unirrigated circumstances a low level of soil moisture deficit (the measure of soil moisture conditions employed by both Willatt and Lal) will have been associated with cooler, more humid atmospheric conditions which in the present circumstance can be expected to increase response to a given soil moisture regime. Consequently, a low level of soil moisture deficits under natural weather will be associated with a high level of yield. When the correlation between soil moisture deficit and atmospheric environmental factors is modified by irrigation, treatments which result in low levels of soil moisture deficit will usually be associated with hot, dry conditions which, in the present case, are unfavorable to growth and consequently produce low levels of yield regardless of soil moisture conditions.

Since the correlation of other environmental variables with rainfall is not perfect, there may still be some cool, humid years in which little rain falls and yields of irrigated tea may approach those which receive plenty of well-distributed rainfall. This appears to be the case in most years in Southern Tanzania (Carr) where tea is grown about 4,000 feet higher than the tea in Malawi. Again, analysis of the irrigation experiment mentioned above shows that the response to reduction in soil moisture deficits was generally smaller than predicted by Willatt's regressions by an amount which varied from year to year. This yearly variation appeared to depend on the values of atmospheric, environmental variables which could be measured by the number of days of low evaporation (less than 0.20 cm. per day); in the irrigation experiment these were independent of soil moisture conditions. The coefficient of this variable was significant and positively related to yield (Palmer-Jones). When most days had low evaporation, the response of tea was similar to that described by Willatt's function. Details of this work, which are not relevant to the points being made here, are given by Palmer-Jones.

Unfortunately, reliable data from unirrigated tea were not available to estimate the response function, including soil moisture conditions and the number of days of low evaporation. In any case, the estimation of such a function from only rainfed conditions might run into the problem of multicollinearity between independent variables, since in unirrigated conditions, the number of days of low evaporation would be correlated with soil moisture

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[3]
$$Etw = \sum_{t=1}^{36} (M_t),$$

where

$$M_t = (\min E_t, R_t);$$

t are the ten-day periods in a year numbered from 1 to 36, $E_t = 0.85 \times$ Class "A" USWB evaporation pan in period t in inches—an estimate of actual evapo-transpiration, and R_t = rainfall in period t in inches.

[4] Further examination (Palmer-Jones) of the hypothesis suggested that there was in fact no correlation between annual yields and Etwn. The original result was due to variations in the periods over which yield and Etw were summed. Shaxson's result was due to pruning which artificially reduces yields and Etw one year in three. Grouping years by stage of prune resulted in nonsignificant correlation coefficients ($P > 0.05$). The significant partial regression coefficient of Etwn found by Palmer-Jones was due to the inclusion of years of prune.

conditions. Furthermore, yield will be affected by soil moisture conditions throughout the life of the plant and, consequently, independent variables for soil moisture at several points should be included. However, in rainfed conditions there will tend to be serial correlation among these variables in a given year; a large soil moisture deficit early in the season will be associated with larger deficits later.[5]

To summarize, the results of yield-weather studies of tea in Malawi suggest that irrigation will not generally have the same effect on yield as rainfall or "ideal" weather due to the different associations between rainfall and irrigation and atmospheric environmental variables which affect response to soil moisture conditions. Even the inclusion of independent variables to reflect the influence of these factors will not be without dangers when the estimation of regression coefficients is based on natural weather—yield data alone; this is due to the potential multicollinearity between atmospheric environmental variables and soil moisture conditions at any one time and serial correlation of, at least, soil moisture conditions.

A properly designed irrigation experiment would allow the effect on yield of different quantities of water applied, and hence the effect of different soil moisture conditions in each period in the irrigation season to be evaluated. By following each set of soil moisture conditions in one period by several different sets in the next period, the multicollinearity between variables and serial correlation of soil moisture conditions in different periods will be avoided.

[5] This serial correlation will also be apparent in some irrigation experiments where typically the same rule about when and how much irrigation water to apply is used through the irrigation season on a given plot. Thus, if the experiment compares irrigation at 3-inch deficits with irrigation at 1.5-inch deficits, final yield could be due to any of the deficits each of which will be correlated over time. A similar problem arises in experiments which irrigate at a constant volumetric soil moisture content. The solution is to apply different rules at different times (Palmer-Jones).

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Uncertainty and the Choice of Tenure Arrangements: Some Hypotheses

Samuel P. S. Ho

Recently, in this *Journal,* Adams and Rask and Boxley discussed the problem of tenure arrangement, in particular the apparent misallocation of resources under share tenancy. Their analyses operate within a framework of certainty and do not explicitly consider many of the conditions of the lease contract that are subject to negotiation. However, to gain a more complete understanding of why differing tenure arrangements exist and the conditions under which parties to the lease prefer one arrangement over the others, a more realistic framework is required. This paper attempts to move in this direction by relaxing the assumption of certainty. As a first step, we investigate how differing tenure systems alter the risk to landowners and tenants. We then identify and investigate a few of the factors affecting the choice of tenure arrangement when uncertainty is an inherent factor.

Given certainty, landowners and tenants are presumably concerned solely with their income. But when uncertainty is introduced, both the level of income and its variability need to be considered. Uncertainties in farming are caused largely by the uncertainties of nature, changing technology and market conditions, factors that are beyond the control of, and often also the insurability by, individual farmers. In other words, a farm produces not a known income but a probability distribution of income. Given a probability distribution of income that can be produced from a piece of land, the probability distribution of the landowner's income and that of the tenant-peasant differ significantly when the land is operated under different tenure arrangements.

Assume that the net income from farming one unit of land, x, is a random variable with a distribution, $f(x)$.[1] Further assume that $f(x)$ can be fully described by its mean (μ_x) and variance (σ_x^2). Given $f(x)$, table 1 summarizes the means and variances of the landlord's income and those of the tenant when the land is operated under several common tenure arrangements.

Most of the results are familiar, so it is only necessary to briefly review them. Under the owner-operator system, the owner bears the risk of income variations.[2] Under the fixed rent arrangement, the landowner is assured of a fixed nominal income and the tenant bears all the risk.[3] Under the crop-share arrangement, the landlord and the tenant split the risk of income variations in proportion to their respective shares of income.[4]

The fixed rent contract with escape clause is perhaps less familiar than the other arrangements. The purpose of the escape clause is to permit the tenant to pay a reduced rent, βR ($0 \leq \beta \leq 1$), when farm income falls below some critical level, x^*.[5] Following are two sample escape clauses found in rental contracts concluded in China in the 1920s and 1930s. The first example is from a fixed rent contract with escape clause from Tsinghai province: ". . . the [aforementioned] rental rate is subject to adjustment according to local customs in a famine year" (China, pp. 54–55).

The second example is from a fixed rent contract with escape clause from Anhwei province: ". . . the landlord is invited to inspect the fields damaged by insects, flood, or drought, and rent is adjusted according to the extent of damage . . ." (Kuo and Hung, p. 62).

In the first example, x^* is defined as famine condition and β, the extent of rent reduction, is only stated as that determined by "local custom." The second sample escape clause is a more compli-

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[1] Net income is gross receipts from farming minus all costs except that of labor and land.

[2] Under the owner-operator system, the peasant bears no risk if it is assumed (as we do in table 1) that he can always find work as a hired laborer. However, once this unrealistic assumption is relaxed, then the peasant must bear the risk of not finding work, i.e., var(Y_t) is no longer zero.

[3] The assumption here is that land is the only input supplied by the landowner. This is, of course, only one of the many possible arrangements. Sometimes landowners also supply some variable inputs, e.g., the services of draft animals. In these cases, the landowners usually receive a larger cash rent but bear the risk of variation in input prices. Finally, unless the rent in prepaid, the landlord must bear the risk of rent default.

[4] For simplicity, we assume that output and production costs are shared in the same proportion. Often, this is not the case. If the tenant bears all the production costs, he necessarily also bears the risk of variations in production costs and only shares with the landowner the risk of variations in produce prices and yields. To take account of the many ways variable costs may be divided between landowners and tenants would complicate our analysis without yielding additional insights into the issues under examination.

[5] This type of asymmetric (in the sense that the landlord's rental income is reduced when farm income is low, but is not increased when farm income is high) escape clause is probably most common. But there is no reason why escape clauses cannot be symmetric.

Table 1. Means and Variances of Landlord's and Tenant's Income under Different Tenure Arrangements

Tenure System	Landowner		Tenant-Labor	
	$E(Y_l)$	$\text{Var}(Y_l)$	$E(Y_t)$	$\text{Var}(Y_t)$
Owner-operator				
$Y_l = x - W$ $Y_t = W$	$\mu_x - W$	σ_x^2	W	0
Fixed cash rent				
$Y_l = R$ $Y_t = x - R$	R	0	$\mu_x - R$	σ_x^2
Crop sharing				
$Y_l = rx$ $Y_t = (1 - r)x$	$r\mu_x$	$r^2 \sigma_x^2$	$(1 - r)\mu_x$	$(1 - r)^2\sigma_x^2$
Fixed rent with escape clause				
$Y_l = R,\ x^* < x$ $= \beta R,\ x \le x^*$ $Y_t = x - R,\ x^* < x$ $= x - \beta R,\ x \le x^*$ $0 \le \beta \le 1$	$R - (1 - \beta)R \int_{-\infty}^{x^*} f(x)dx.$	$\int_{-\infty}^{x^*}(\beta R - R^*)^2 f(x)dx$ $+ \int_{x^*}^{\infty}(R - R^*)^2 f(x)dx$	$\mu_x - R + (1 - \beta)R \int_{-\infty}^{x^*} f(x)dx$	$\sigma_x^2 + \int_{-\infty}^{x^*}(\beta R - R^*)^2 f(x)dx$ $+ \int_{x^*}^{\infty}(R - R^*)^2 f(x)dx$ $- 2R(1 - \beta) \int_{-\infty}^{x^*}(\mu_x - x)f(x)dx$

Note: Y_l is landlord's net income, Y_t is tenant's net income, R is cash rent per unit of land, W is wage, r is rental share, x is net income $(Y_t + Y_l)$, μ is mean, σ^2 is variance, and $R^* = R - (1 - \beta)R \int_{-\infty}^{x^*} f(x)dx$.

cated one since it suggests that there may be several β's, each governing a different range of output.

In effect, the escape clause specifies the conditions under which rent default is legally permissible and therefore it tends to increase the variability of the landlord's income, $\text{var}(Y_l)$, and to reduce the variability of the tenant's income, $\text{var}(Y_t)$. Given R, the expected value of the landlord's income is, of course, also reduced and that of the tenant increased. In general, other things being equal, the closer β is to zero and the higher x^* is, the lower would be the landlord's expected rental income and the higher would be the tenant's expected income. An increase in β has the effect of decreasing $\text{var}(Y_l)$ and increasing $\text{var}(Y_t)$. However, the effect on $\text{var}(Y_l)$ and $\text{var}(Y_t)$ of an increase in x^* is more difficult to predict since $\frac{\partial \text{var}(Y_l)}{\partial x^*}$ and $\frac{\partial \text{var}(Y_t)}{\partial x^*}$ may be either positive or negative.

Since the landowner's income and its variability, as well as those of the tenant, are significantly different under different forms of tenure arrangement, the choice of tenure arrangement clearly depends on the attitude toward risk, the variability in income, and the available trade-off between the level of income and its variability implicit in the various tenure arrangements.

One interesting case is when the peasant's attitude toward risk and therefore the choice of tenure arrangement may be strongly influenced by the position of his income (Y_t) relative to the following three income levels: the minimum level required for physical survival (Y_{mp}), the minimum social subsistence level (Y_{ms}), and the desired level (Y_d) (Miracle, pp. 295–300; Wharton, pp. 29–32). For a given environment, Y_{mp}, the level of income necessary to maintain life is constant; Y_{ms}, on the other hand, is a socially and culturally determined minimum. It is what the peasant's immediate society considers, at a given moment in time, to be the minimum acceptable level of income; Y_{ms} is at least equal to but usually higher than Y_{mp}. The extent to which Y_{ms} exceeds Y_{mp} depends on the average standards of living historically, as well as on other social and cultural factors. The higher the historical standards of living, the higher is Y_{ms}. Over time, as the average living standards rise, we would also expect Y_{ms} to rise, but with a lag; Y_d, the desired level of income, reflects the peasant's aspiration, and as such it is flexible over time and can be changed quickly. The relationship between these three levels of income is most likely $Y_{mp} \leq Y_{ms} \leq Y_d$. The peasant has the dual objective of attaining Y_d and remaining above both Y_{ms} and Y_{mp}. We would expect that the closer he is to Y_{ms} (or Y_{mp}), the greater is the weight given to the objective of remaining above it.

To illustrate, consider how a peasant's choice of rental contract might change as his relative income position is altered. Assume that he is faced with the choice of selecting between two rental contracts, one being a fixed-rent contract (f-r) with rent R and the other a crop-sharing contract (c-s) with rental share r. Further assume that the peasant, from his own experience or from historical records, knows the mean (μ_x) and standard deviation (σ_x) of x, the income from the farm in question. We shall argue that depending on how the peasant's expected income $E(Y_t)$ is related to Y_{mp}, Y_{ms}, and Y_d, his choice of tenure arrangement may be very different.

Figure 1 depicts the condition facing most peasants in an agriculture before the beginning of rapid progress. In such an economy, we would expect Y_{ms} to exceed Y_{mp} but by only a small margin; μ_x is likely to be at a level at which the peasant's expected income under either rental systems would be near Y_{ms}. In this situation, because he is not only very close to his social subsistence but also close to his physical subsistence, the peasant would have a strong aversion to any variability in his income. Thus, even though his expected income is lower under the share contract than under the fixed rent contract, $(E(Y_t)_{c-s} < E(Y_t)_{f-r})$, he would prefer the share contract for its lower variance and the lesser likelihood that his income would fall below Y_{mp}.[6]

In a commercialized and fairly well-developed agriculture, we would expect both Y_{ms} and Y_d to be substantially higher than Y_{mp}. Most importantly, μ_x is likely to be significantly higher than in the subsistence case, so that the tenant finds himself with an expected income, under either crop-sharing or fixed rent contract, sufficiently high that he is unlikely to fall below Y_{mp} or Y_{ms}. He is, therefore, less concerned with remaining above Y_{ms} than with achieving his desired level of income. Because his expected income is higher and because he has a greater chance of achieving Y_d under the fixed rent contract than under the share contract, he is likely to prefer the former.[7]

It is important to note that tenure arrangements may influence yield variations (or uncertainty) in the long run through their effect on land conservation. Ciriacy-Wantrup suggests that when tenants are responsible for conservation decisions, fixed rent may be undesirable from the standpoint of conservation, because during recessions the lower income of tenants tends to increase their time preference rates and lead to depletion [pp. 103–9, 155–57]. An easy remedy of this problem is to include in the lease contract a clause requiring the tenant to return the land in the same condition as he

[6] In figure 1 the income lines for the two tenure arrangements are positioned so that they intersect to the left of μ_x; thus at μ_x, the tenant's income from the fixed cash lease is greater than that from the share lease. This is likely since under crop sharing, landlords share the risk of farming and often also participate in farming decisions and consequently would receive a higher return. If the income lines intersect to the right of μ_x, then the share lease would be preferred by the tenant for its higher expected income as well as its lower variance.

[7] Again, we assume that the two income lines in this case, as in figure 1, intersect to the left of μ_x.

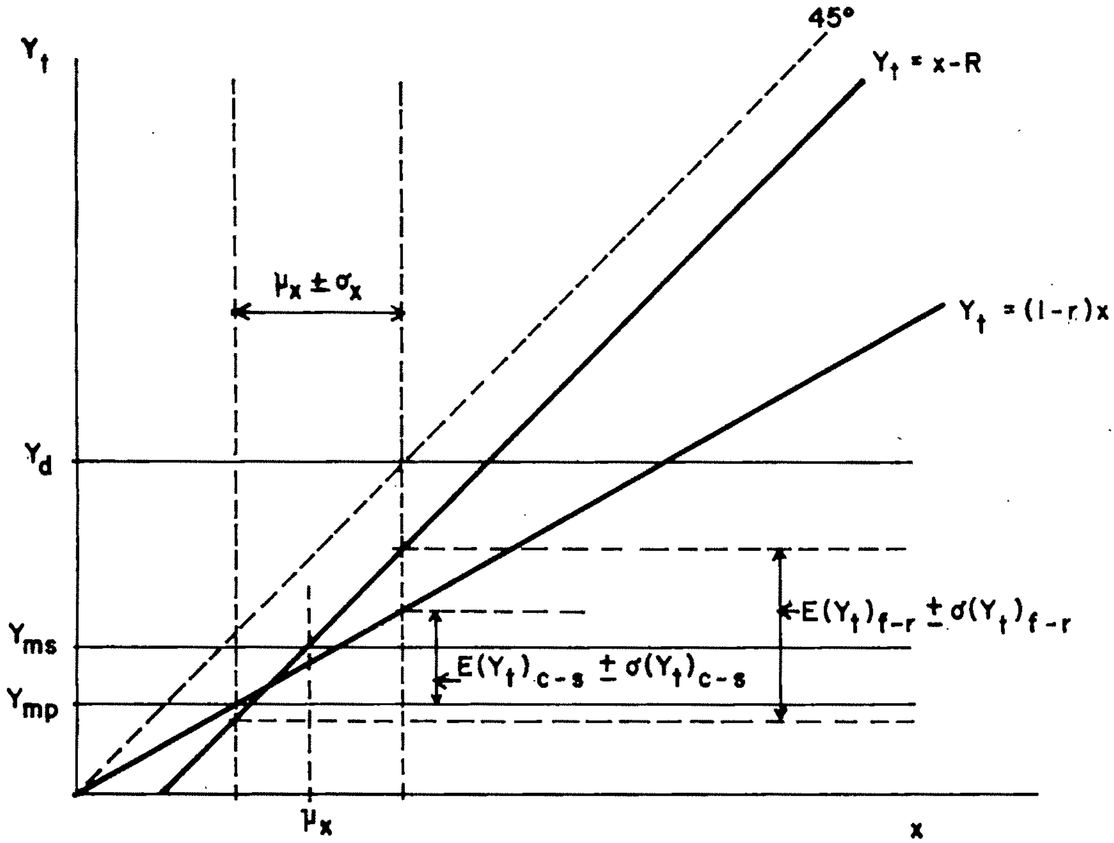

Figure 1. Choice of rental contract when peasant's expected income is low

received it. Also, this problem does not exist when tenants are not directly involved in conservation decisions. For example, landowners may specify in the lease the crops to be planted and their order of rotation. The share lease may also affect yields in the long run, if the landowner belongs to a low income group and participates in conservation decisions. In this case, a fall in yield or product prices reduces the value of the landlord's share and thereby increases his time preference rate and leads to depletion.

Up to this point, our analysis has focused only on the first and the second moments of the probability distribution. There is no reason, however, why we should not also be concerned with other aspects of the distribution. We are aware that tenure arrangements can affect the probability distribution of the tenant's income in ways other than to change its mean and variance. For instance, under the fixed rent contract with a simple escape clause, the distribution of the tenant's income is different from that obtained under other tenure arrangements, not only because its mean and variance are different, but also because its skewness tends to be different. This latter characteristic, as we shall see, may be of some importance. In our treatment of the farmer's behavior under uncertainty, we have also assumed that he ranks his opportunities by only two measures—mean and variance. This simplification is done at some cost. For example, a person's behavior is normally influenced by his desire to avoid extreme values, particularly the low extremes. He is therefore not indifferent to two distributions with equal means and variances but unequal skewness. Given these factors, our previous discussion of choice of tenure arrangement would seem to require qualification.

It is reasonable to assume that people generally attempt to avoid or to reduce the probability of very low income. In this regard, peasants are surely no exception. Of the rental contracts discussed, only the fixed rent contract with escape clause is solely concerned with reducing the tenant's probability of disaster. The peasant who pays the premium for the escape clause is insuring not so much against variability as against the disaster of starvation. One can easily think of peasants who would prefer a fixed rent contract with a simple escape clause to sharecropping, even if the share contract would give him the same expected income and a significantly lower variance.

The lack of a well-defined, one-to-one relationship between inputs and output, and consequently the importance of entrepreneurship, also creates

additional sources of uncertainty for the landowners and the peasants. Uncertainty is introduced by the existence of inputs of variable specification, e.g., the nature of the labor input is never precisely defined. The lack of a well-defined production function and the fact that input of fixed specification may result in variable performance provide scope for entrepreneurship (Leibenstein). But since people are endowed with different entrepreneurial capacities, the scope for entrepreneurship becomes another source of uncertainty. Considering these factors alone, the choice of rental contract would seem to depend partly on whether the uncertainty is perceived to be caused by the scope of entrepreneurship or by the variable specification of the inputs and partly on the tenant and landlord's assessments of their own entrepreneurial capacity.

If the main source of uncertainty is that inputs are of variable specification, then the landlord and the tenant, to protect themselves, are likely to prefer different types of rental contracts. For instance, to guard against the uncertainty of tenant labor, the specification of which is never really completely spelled out in a rental contract, the landlord would prefer a fixed rent contract. Similarly, a new tenant, to protect himself against the uncertain quality of unfamiliar land, is likely to prefer sharecropping. However, once the landlord and the tenant are better acquainted, this type of uncertainty becomes less important.

If the source of uncertainty is the scope for entrepreneurship at the farm level, then a landlord with the necessary entrepreneurial skills is likely to prefer the share contract to the fixed rent contract and take part in farm decisions so as to capture a share of the entrepreneurial income. Indeed, the landlord may even prefer sharecropping to a wage system where presumably he can capture all the entrepreneurial income. This is because the implicit reward-penalty provision of crop-sharing tends to reduce the landlord's supervision cost in that a sharecropper has greater incentive than a wage earner to follow closely the landlord's instructions. Of course, if the landlord does not have the necessary entrepreneurial ability (or does not wish to exercise it), he would attempt to protect himself from the uncertainty of entrepreneurial judgment of others by choosing a fixed rent contract. Under similar conditions, a tenant lacking the required entrepreneurial skills is likely to prefer the share contract so that he may share with the landlord both the responsibility and the uncertainty of entrepreneurial judgment and decision making. However, if the tenant is more positive in his assessment of his entrepreneurial ability than of his landlord's, he would prefer the fixed rent contract so that he may capture all the entrepreneurial income. If this argument is valid, then we would expect the share contract to be a popular arrangement between experienced farmer-landlords and young, inexperienced tenants. In the United States, at least, there seems to be some evidence of this [Gray and Turner, p. 26].

This paper has focussed on only one aspect of tenure arrangements—that they expose the landowner and the peasant to differing degrees of uncertainty. We have argued that the attitude toward risk and therefore the choice of tenure arrangement may be different depending on one's relative income position and entrepreneurial capacity. However, tenure arrangements also differ in many other important respects. They differ in that they require varying degrees of participation by the landowner in the operation of the farm, they have different transaction costs, and they impose different constraints on the tenant-peasant. Our understanding of this very important rural institution will remain imperfect until these differing aspects of tenure arrangements are brought together in an integrated and more general analysis.

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Evaluation of Alternative Milk Marketing Arrangements in Southeast Florida

Anthony A. Prato

Technical and economic developments over the past two decades have altered the structure, conduct, and performance of the U.S. dairy industry. Two noteworthy developments are the successful organization of milk producers into interregional cooperatives and backward integration of food retailers into milk processing. Interregional cooperatives have increased the market power of member producers as evidenced by their ability to obtain Class I premiums for fluid milk.[1] Retailer-processor integration has improved the bargaining position of food retailers in their dealings with milk processors.

The purpose of this paper is to evaluate the potential impact of an interregional milk producers cooperative and various degrees of retailer-processor integration on the prices and returns to milk producers in southeast Florida (the area covered by Federal Milk Market Order 13).[2] Milk producers in Federal Order 13 do not belong to an interregional cooperative nor is retailer-processor integration widespread. However, the industry is concerned with the possible impacts of such arrangements on returns to milk producers and processors.

Basic Model

Various methods have been used to study the problems of food and agricultural industries. Wide use has been made of economic models that determine the optimal allocation of product supplies among alternative markets (Kloth and Blakley; Prato and Havlicek; Amin; McClelland, Polopolus, and Myers). Optimization models are somewhat restrictive for analyzing the impact of changes in economic structure and organization on industry performance and have a limited capacity to handle the time-related aspects of industrial behavior. Systems analysis can handle structural change and dynamic behavior more easily. It has been successfully used to study the consequences of alternative growth and development plans (Halter, Hayenga, and Manetsch) and a wide range of economic problems (Halter and Miller; Raulerson and Langham). Systems analysis typically involves the development of a simulation model that describes decision-making behavior. This analysis is based on the industrial dynamics (simulation) approach developed by Forrester.

The general procedure was to construct and validate a so-called basic model of the southeast Florida milk market. Impacts of an interregional cooperative and retailer-processor integration were analyzed using modifications of the basic model. The basic model consists of a system of seventy-five nonstochastic equations. Model parameters represent conditions in federal order 13 during the 1966–69 period. Three major subsystems make up the model: the physical movement of milk from production to consumption, the determination of producer, processor, and consumer prices, and the determination of returns to retailers, processors, and producers.

The milk production rate is a function of expected consumer utilization of milk and the production incentive.[3] Expected utilization measures the normal pattern of milk consumption while the production incentive measures changes in the revenue-cost position of producers. When producer revenues increase (decrease) relative to production costs, milk production increases (decreases) according to a production schedule. This and other schedules were selected according to their ability to simulate the time-related behavior of selected variables. Rates of allocation of milk to Class I and Class II uses are a function of the proportion of milk that processors allocate to these uses which in turn depends on retail utilization of Class I and Class II milk.[4] Milk allocated to Class II uses is computed as a residual, i.e., the Class II allocation proportion is one minus the Class I allocation proportion. Consumer utilization was generated by summing seasonal and time trends. Retail milk prices were not allowed to affect consumer utiliza-

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[1] Class I premiums cannot be completely attributed to bargaining efforts of cooperatives. Premiums can also reflect an imbalance between supply and demand, specifically excess demand.

[2] Data for Upper Florida and Tampa Bay federal orders were inadequate so they were not included in the analysis.

[3] Objections might arise from making production a function of consumption (consumer utilization in the model). While this specification would be inappropriate in an econometric model, the industrial dynamics approach does not require use of econometric-type supply and demand relationships.

[4] During the study period, Class I products included whole milk, skim milk, low fat milk, and chocolate milk. Class II products included buttermilk, flavored drinks, half and half, table cream, sour cream, ice cream, ice milk, and sherbet. Current classifications are somewhat different.

tion due to the lack of conclusive evidence that milk prices affect consumption (Prato 1973).

Minimum Class I and Class II producer prices are determined by adding a price differential (essentially transportation costs) to the Midwest basic formula price. Blend price is a weighted average of minimum producer prices with Class I and II allocation rates as weights. Consumer prices are a function of farm prices. Processor prices are derived by subtracting retail price margins from consumer prices.

Total consumer expenditures, processor net returns, and producer net returns are determined by subtracting costs and/or payments from total returns. For example, processor net returns are determined by deducting payments to producers and assembly, processing, and distribution costs from total processor returns. For a complete description of the model, see Prato (1975).

Since the basic model is nonstochastic, its equations cannot be judged by conventional measures of statistical reliability (standard errors, R^2, etc.). The model was validated by comparing the 1966–69 simulated and actual values of six variables (Fla. CLRS; Nord, USDA). Percentage differences between the observed and simulated values were smallest for blend price (1.51%), followed by producer deliveries (1.80%), Class I utilization (2.16%), proportion of milk allocated to Class I uses (2.53%) and total producer returns (2.55%).[5] The percentage difference was greatest for Class II utilization (17.56%). This inaccuracy may be due to the importation of Class II milk to southeast Florida (which is not accounted for in the model) and the inherently greater variation in Class II utilization. Based on these comparisons, the basic model was judged to be an acceptable mathematical representation of the southeast Florida milk market.

Interregional Cooperative

The cooperative model was used to analyze changes in net returns to producers, processors, and retailers that might occur if some Florida producers joined an interregional cooperative. It was constructed by altering the basic model to reflect structural and economic adjustments based on the experience of the North Central states (Jacobson and Hoddick). Adjustments are as follows. (a) Forty-two percent of the milk produced is marketed through the interregional cooperative. The remaining 58% is sold by independent producers. (*b*) Processor-oriented services provided by the cooperative enable the cooperative to negotiate a Class I premium of 30.5¢ per hundredweight on all milk.[6] (*c*) Processor-oriented services provided by the cooperative permit milk processors to reduce distribution costs on member-produced milk by 11.6¢ per hundredweight. (*d*) To finance the producer-oriented services rendered by the cooperative, coop member producers pay a 10¢ per hundredweight service fee (retained by the cooperative). (*e*) Coop member producers sell all their milk through the cooperative and independent producers sell all their milk independently of the cooperative. The distinction between member- and nonmember-produced milk was not carried over to the processor and retail segments.

Values for the cooperative model exceed those for the basic model for all six variables. The largest difference is for producer net returns which is $514.3 thousand (38%) over the entire period. Of this difference, member producers received $195.4 thousand (38%) and nonmember producers received $318.9 thousand (58%). Accumulated processor net returns for the period were $76.8 thousand (0.26%) and accumulated retailer returns were $136 thousand (2.3%) higher under the cooperative model. The monthly production rate and Class I utilization would increase by only 1% and Class II utilization by 3%.

Processor-Retailer Integration

Impacts of processor-retailer integration on returns to processors and retailers were analyzed using a modification of the basic model referred to as the integration model. Integrated processors were assumed to have lower per unit processing and distribution costs than independent processors.[7] Due to the lack of information concerning per unit costs

Table 1. Cost Differentials for Integrated and Independent Processing Plants

	Efficiency Level					
	I	II	III	I	II	III
Activity	Integrated Plant			Independent Plant		
			%[a]			
Processing	−5	−10	−15	15	10	5
Distribution	−2	− 5	− 8	8	5	2

[a] Percentage deviation above or below figures used in basic model; namely, $1.50 and $0.50 per cwt. for Class I and Class II processing costs, respectively, and $2.50 per cwt. for distribution costs.

[5] Percentage differences were computed on a quarterly basis, i.e., the average of the monthly figures for each quarter.

[6] A reviewer contends that a cooperative must control at least 70% of the milk in a given market before it can secure premiums. The 42% figure used here is a national average for milk controlled by cooperatives. The model could be rerun using higher percentages.

[7] A reviewer pointed out that Parker's study shows there are no substantial differences in processing costs for integrated versus independent plants. This point is still open to debate. If the 20% diffference used in this study is judged to be excessive, then the revenue differences reported in table 2 and corresponding conclusions would have to be revised.

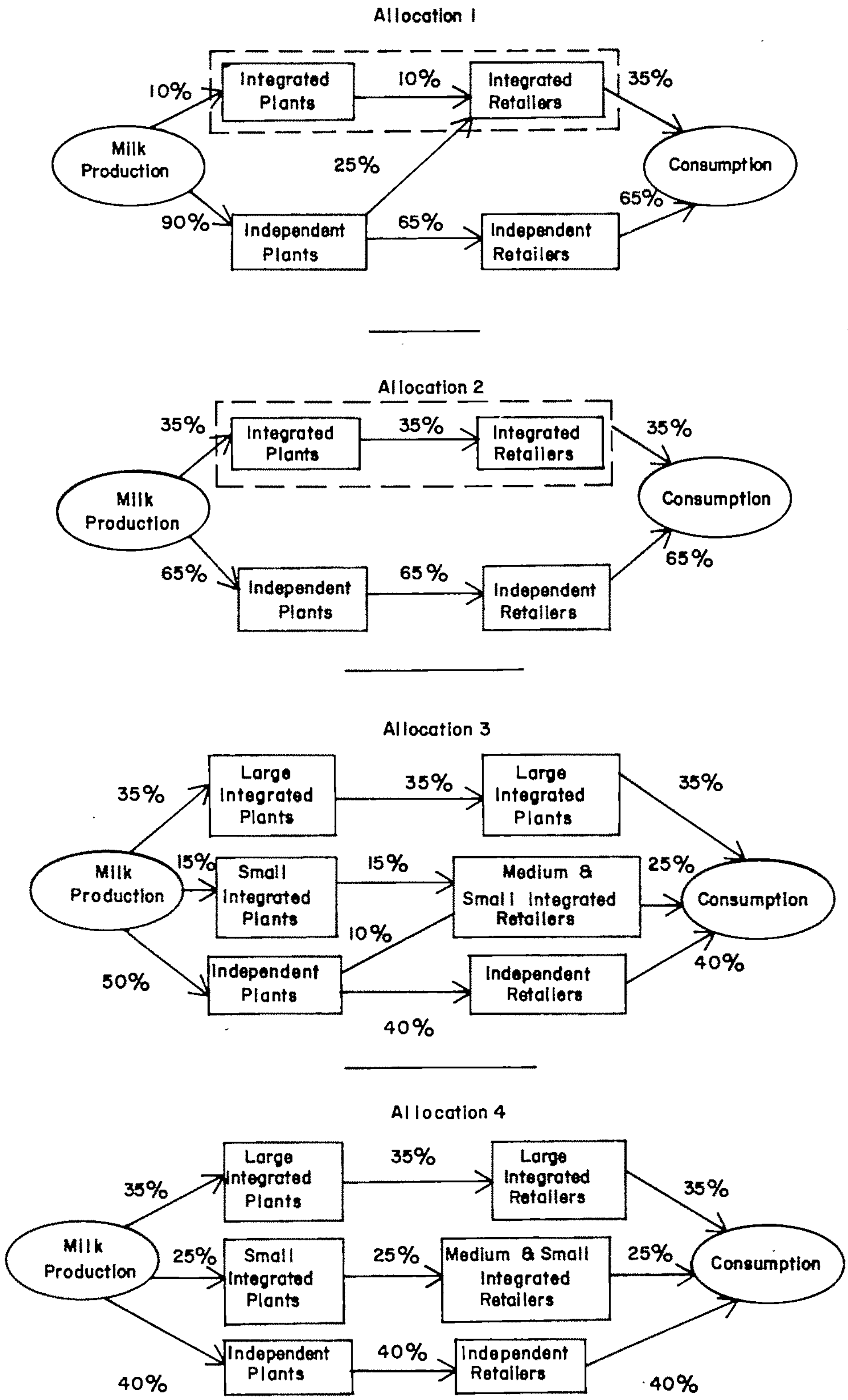

Figure 1. Alternative allocations of milk between integrated and independent plants and retailers

Table 2. Accumulated Processor Net Returns, Basic versus Cooperative Models, 1966–69

Efficiency I							
Basic[a]				Cooperative[b]			
Allocation							
1	2	3	4	1	2	3	4
$1,000							
2,490	2,786	2,915	3,001	2,591	2,859	2,989	2,561
Efficiency II							
2,813	3,108	3,219	3,294	2,886	3,183	3,296	3,371
Efficiency III							
3,136	3,431	3,525	3,587	3,211	3,509	3,603	3,667

[a] Using production and retail segments of basic model.
[b] Using production and retail segments of cooperative model.

of operating integrated versus independent plants, cost differences were defined in terms of percentage deviations from costs used in basic model. Three cost differences or efficiency levels were specified under the integration model (table 1). For each efficiency level, four allocations of producer milk between integrated and independent plants were simulated (fig. 1) Although the difference in processing efficiency between integrated and independent plants remains constant at 20% (table 1), the distribution of milk between integrated and independent plants and hence overall efficiency varies over allocation. Per unit processing and distribution costs were assumed to be the same for small, medium, and large integrated plants (fig. 1).

Each of the four allocations at three levels of efficiency was run with the producer and retail segments of the basic and cooperative models. This implies that the total quantities of milk and price levels in the integration model are the same as in the basic or cooperative model. Processor net returns under all allocations and efficiency levels are greater for the cooperative-integration than the basic-integration model (table 2). This illustrates two points. First, as the proportion of milk handled by integrated plants increases, total processor net returns increase for every level of efficiency. Second, the greater the cost reductions due to integration, the greater the increase in processor net returns. Table 2 also shows the trade-offs for increasing processor net returns by increasing the extent of integration (moving from allocation 1 to allocation 4) versus increasing the efficiency of integrated plants (moving from efficiency I to III). For example, moving from allocation 1 to 2 under basic integration and efficiency I increases processor net returns from $2,490 to $2,786 thousand, or 12%. Such comparisons give insight into the structural alternatives for improving net returns by integration.

Comparing processor net revenues in the presence and absence of integration shows that processor-retailer integration might result in no gain in total net revenue to processors if only efficiency I can be reached, minor gains under efficiency II, and significant gains under efficiency III. Moving from a cooperative structure to an integrated structure does not increase net returns unless at least 10% of the milk moves through very efficient, integrated plants or at least 65% moves through moderately efficient integrated plants.

Conclusions

Conclusions drawn from this study are conditional on the assumptions and parameter values embedded in the models. Operation of an interregional cooperative in southeast Florida would have only a negligible effect on milk production and Class I and II utilization. Net returns to producers would average 38% or $514.3 thousand greater over the 1966–69 period with the operation of an interregional cooperative. Of this amount, member producers would receive about 38% and nonmember producers 62%, if members accounted for 42% of production. Overall processor net returns would be $76.8 thousand greater (0.26%) and retailer net returns would be $136 thousand greater (2.34%) with a cooperative. Processor-retailer integration would not increase net returns over the levels in a nonintegrated structure unless at least 65% of the milk produced is moved through moderately efficient integrated plants or at least 35% through highly efficient integrated plants.

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Industry Demand for Egg Clearinghouse Services

Bill R. Miller and Dennis P. Helmreich

Since 1950, significant changes in the production and marketing of shell eggs have occurred. Along with larger and more vertically integrated production units came more direct methods of marketing. Eggs were forwarded by jobbers or producers to supermarket warehouses or retail stores. Large central markets (Los Angeles, Chicago, New York, etc.) fell into disuse as they were bypassed by new shell egg market channels (Rogers and Voss). Hence, the market price quotes were based on a rapidly diminishing volume, but these quotes were used as a basis for pricing eggs which were traded directly (Rogers).

Another facet of the growth in direct marketing is the evolution in the market structure to fewer and larger egg producers. This increase in size of firms entails more uniform production methods (placements, feeding, medication, etc.) and a more uniform product. Egg producers are now producing large quantities of uniform, high quality eggs. This trend has lent credibility to the idea of trading gradeable nest run (GNR) shell eggs. This adds still another dimension to the pricing problem since, historically, prices have been quoted on a graded basis.

The Problem and Objective

During the latter half of the 1960s, a federally funded, comprehensive program of research on egg pricing was conducted. The results of this study pointed out many problems associated with market decentralization (Rogers and Voss). In an attempt to fill the price information void left by decentralization, United Egg Producers developed a short-run price projection model to provide a base point price series (Miller and Masters). Through use of this model, prices were published for two years, but its function has now been replaced by Egg Clearinghouse, Incorporated (ECI). ECI began trading eggs in November 1971. ECI trading probably does not completely reflect the current supply and demand situation. Apparently most eggs are still traded on the basis of the Urner-Barry quote or U.S. Department of Agriculture prices, but the ECI auction method of trading has the potential for more accurately establishing the price of GNR eggs at the wholesale level. USDA has established nest run specifications for determining weight classes and quality standards of GNR eggs. Trading eggs through a clearinghouse can also eliminate the need for dual grading, once at the point of origin and again at the point of destination, but will the services of the clearinghouse be acceptable to the industry? Continued acceptance and expansion of demand for this form of trading is necessary if it is to provide an efficient market price quotation for eggs. Current market price information for GNR eggs has become a vital necessity since futures contracts for GNR began trading July 1, 1974 on the Chicago Mercantile Exchange.

A study with several broad objectives was implemented in 1973 and this paper reports on one objective: project the demand for the new services of ECI.

The Data and Its Analysis

Research on acceptance of new products and services has been a focus of study for some time. One of the most common phenomena observed is an increase in sales during the introductory period when newness of the product apparently has an experimental appeal to some buyers (Eskin, Massey). These buyers try the product; then, finding it not to their liking or not fulfilling their expectations, they become inactive in the market. We hypothesized in this research that a comparison of the inactive member users of the new marketing services offered by ECI compared to the active member users would yield estimates to aid in forecasting demand among the population not yet fully exposed to, or informed about, ECI.

All members of ECI (eighty-two), effective June 1, 1973, were polled via mail questionnaire concerning their production and marketing practices and their acceptance of ECI. At the same time, a sample of eighty-five non-ECI members was chosen at random from a master list developed to represent the national poultry industry. A second questionnaire was mailed to nonrespondents after three weeks. Several nonrespondents were interviewed personally, and a random sampling of the remaining nonrespondents were interviewed by telephone. A total of fifty-three responses were obtained from the ECI members and forty-four from nonmembers.

The data were first subjected to tabular analysis to determine which variables from the questionnaires were important in terms of the amount of trade through ECI. The size of firm cross-classified

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with all other variables from the questionnaire yielded results which suggested variables that were significantly related to the volume of business transacted through ECI.

The integrated, multifunction nature of the egg industry was apparent among ECI firms. Typically, they are involved in commission sales and purchasing for resale in addition to egg production. Only nine of fifty-three ECI members did not own a production flock. Furthermore, flock ownership was about equally distributed by size of firm, table 1, where size of firm is defined as eggs purchased, produced, or sold on a commission basis during the period of the study. Flock owners were among the largest firms; they averaged 806,000 cases handled compared to only 455,000 for nonowners.

In view of the integrated structure of the egg industry, it may be logical to ask whether they need auction markets. ECI members were asked to estimate the amount of eggs purchased (fill-in) or sold (surplus) outside of "normal" or regular marketing channels. Since fill-in and surplus are common terms among many industry members they appeared to have no difficulty completing this part of the questionnaire.

Only in the smallest firm size category, less than 162,000 cases handled, was the volume of clearinghouse trade comparable to the volume of fill-in and surplus eggs. In all other size categories, clearinghouse trade was less than 15% of fill-in and surplus and in one class, 450,000 to 840,000 cases, was less than 1%, table 1. Fill-in and surplus eggs could be traded on an auction market, but currently ECI is not capturing the existing market among its own members. Other evidence of disuse by members is the large volume of eggs sold to breaking plants relative to the size of clearinghouse trade, table 1. There is a period of the day when breaking plant stock is traded by ECI.

Apparently, the low level of trade among members is not because of recognized dissatisfaction with the service. For example, there were twenty-two members who had purchased eggs through ECI, and all indicated that they were well satisfied with the quality received. Only three indicated that egg size of the nest run product was smaller than expected. All purchasers planned to continue trading with ECI. Sellers, likewise, were generally satisfied with the service. In fact, of the four ECI members who were not satisfied and planned to discontinue their membership, none had ever purchased or sold eggs through the clearinghouse.

Of perhaps greater concern is the appeal of the clearinghouse to nonmembers. Our survey of nonmembers indicates that ECI firms are, on the average, about twice as large as nonmembers. If size or trade attributes associated with size are an important attribute of ECI trade, then long-run expansion may be difficult. We did find size to be important in attempts to discriminate between users and nonusers.

During the eighteen-month period of the study, there were eighteen members who did not trade, but they had been active in prior months. Apparently, they had tried using the service but found no continuing business use for it even though on the questionnaire they expressed general satisfaction. As it is not uncommon for purchasers of a new product or service to drop out of the market, our hypothesis was that these eighteen inactive users who were not repeating use of the service had characteristics that differentiated them from active users. Since our questions to nonmembers were parallel to questions asked of ECI members, we can compare characteristics of active ECI users with firms in the egg industry who are potential members. Discriminant analysis is one method of comparison and several discriminant models were applied to the groups of thirty-five active and eighteen inactive ECI members (Tintner). The model whose economic logic and statistical properties seemed to support the hypothesis of two different

Table 1. Average Ownership, Production, and Marketing Characteristics of ECI Members, January 1972–June 1973

Size of Firm (100,000 cases handled)	Number of Firms[a]	Number of Flock Owners	Average Volume of Production	Average Volume of Clearinghouse Trade	Average Volume of Fill-in Eggs Purchased	Average Volume of Surplus Eggs Sold	Average Volume of Eggs Sent to Breaking Plant
			100,000 cases				
Less than 1.621	10	8	0.62	0.0169	0.013	0.013	0.280
1.621–2.930	10	8	1.10	0.0384	0.221	0.035	0.418
2.930–4.500	10	8	1.40	0.0277	0.345	0.032	0.286
4.500–8.400	10	7	2.01	0.0163	0.485	1.003	0.836
Over 8.400	10	9	8.14	0.0882	2.153	0.583	1.155
$(F_{4,45})$[b]		N.S.	3.42[c]	2.90[c]	3.44[c]	3.06[c]	3.88[d]

[a] Number of firms is less than total in sample since three respondents failed to indicate size of firm.
[b] Degrees of freedom for F-test of significance of differences among firms of varying size.
[c] Indicates significance at 0.05 probability level.
[d] Indicates significance at 0.01 probability level.

groups contained as characteristics: size of firm, volume of breaking eggs, a satisfaction index of marketing pricing, and flock ownership. The discriminant function was determined to be[1]

$$Z = 0.01606\ X_1 - 0.0363\ X_2 - 0.01765\ X_3 + 0.00554\ X_4,$$

where X_1 = size of firm (in 1,000,000 total cases of eggs handled, January 1972–June 1973); X_2 = ownership of a flock = 0, nonownership = 1, X_3 = volume of eggs sent to breaking plants (in 100,000 cases, January 1972–June 1973); X_4 = index of satisfaction with pricing methods used for purchasing fill-in eggs and selling surplus eggs (value of 1 indicates the highest level, value of 4 is the lowest level); Z = a linear combination of the discriminant variables.

The mean Z for active traders was 0.0109 and was −0.0059 for nontrader members. Thus, a positive coefficient for firm size would project that as firms become larger they are more likely to become ECI members. Furthermore, if the large firm is a flock owner, the probability that it will be an active ECI trader increases. Also, if he is a relatively large flock owner who is dissatisfied with current pricing methods for purchasing fill-in and surplus eggs for his integrated operation, the probability increases again that he will use ECI. Finally, since large flock owners are not generally in the business of producing eggs for breaking plants, a relatively low level of trade with breaking plants is the final variable that will give him the highest probability of actively using ECI.

The discriminant function derived from the fifty-three members of ECI was applied to the observed data on forty-four nonECI members. By employing 90% confidence intervals about the group mean discriminant scores, we found that of the forty-four respondents, only three produced Z values greater than the upper confidence limit of the lower group. This would indicate that only about 7% of the sampled nonmember firms are potential users of the services of ECI. Even less potential is indicated if a higher confidence level is used.

[1] The F-value for the D-square coefficient of the function was 2.004. Variables in the function were chosen based on a cross-classification of volume of trade with all other variables provided by the questionnaire. A more complete description of this choice is presented by Helmreich.

Summary

Only about 7% of firms that do not participate in ECI were forecast as potential users of a clearinghouse for trading GNR eggs. While, on a national basis, this would represent a significant increase in ECI members and in trading, it does not represent a fast growing and universal acceptance.

This estimate should be considered short run as it depends on existing levels of satisfaction with alternate market price plans, firm size, and other characteristics of ECI members. At present, larger than average flock owners who are most dissatisfied with alternate methods of marketing appear to be the best clients for membership. As members, they are trading, in aggregate, less than 3% of their trade volume through ECI. Under these conditions, there appears to be adequate room for growth, since members are generally satisfied with ECI and a substantial fill-in and surplus market of up to 15% of total volume appears to exist among large integrated operations. General acceptance will depend on developing services that are appealing to a much broader segment of the market and will depend on member firms selling a much higher percentage of their total sales through ECI.

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The Effect of Vertical Integration on the Production Efficiency of Beef Cattle Operations

Ahmed A. Araji

Cattle feeding and cow-calf operations are high investment, high risk farm enterprises. Except for those which are integrated, beef cattle enterprises are essentially marginal operations (Breimyer, p. 1). Seckler indicates that costs associated with transportation, buying and selling commission, shrinkage and death loss from the time the animal leaves the ranch until it reaches the packers are estimated between \$10–\$35 per head, depending on how far the animal is transported and how often it changes hands. Farris and Williams estimate the gain of an additional \$10 of net return per head by integrating from the cow herd to the packer. In general, all evidence points toward significant external economies associated with vertical integration in beef production. The internal effect of forward integration on production efficiency, however, has not been adequately analyzed.

Internally, production efficiency is influenced by size of operation and complementary use of resources. Thus, efficiency in beef cattle production is hypothesized as a function of size and system of operation. However, while a large number of studies show that significant economies are associated with size in all systems of beef operations, little research effort was designed to evaluate the effect of size and system on the production efficiency of beef cattle operations. Johnson and Eckert's cost analyses of four feeding systems in Nebraska showed that both system and size affected feeding efficiency, with system being the more important variable. That study, using simple regression, tested the relationship between size and input-utilization efficiency separately for each input and for each feeding system. Kearl, analyzing net income for nine feeding systems, demonstrated that the breeding system which marketed the major part or all of their young cattle as yearlings had a slight advantage over the cow-calf system.

In general, available empirical evidence relative to the effect of size and system on the production efficiency of beef cattle operations is inconclusive. The primary objective of this paper is to estimate production efficiency coefficients for three systems of beef cattle operations (cow-calf, cow-yearling, and completely integrated) and evaluate the effects of size and system on the efficiency of beef production.

Measurement of Production Efficiency

Several methods of measurement of production efficiency have been used by economists. A partial productivity index considers a single factor of production and ignores all other inputs and thus is inadequate as an overall measure of efficiency. Index numbers have been constructed to include all inputs. However, this method of measuring production efficiency suffers from the problem of choosing base years and deciding weights. Cost synthesis approaches also are used to evaluate efficiency, but this method estimates a theoretical function that is optimistic as compared to the best results observed in practice (Farrell, p. 255). A linear programming technique for measuring production efficiency which takes account of all inputs and yet avoids index number problems was developed by Farrell. Efficiency ratings estimated by this model relate the efficiency of plants of varying size and identify the optimum scale plant.

The major limitation inherent in the Farrell model is the assumption of constant returns to scale. A modification of the Farrell model that considers the effect of economies of scale was introduced by Farrell and Fieldhouse. Aigner and Chu, however, express difficulties with Farrell's approach, in that it does not conform to the law of variable proportions and in that the shape of the expansion path needs to be specified in advance (pp. 830–31). Seitz illustrates the applicability of the model proposed by Farrell and Fieldhouse to a wide variety of production functions. The shape of the expansion path need not be specified prior to estimation. He demonstrates that input-output data are expressed to allow the use of linear programming techniques for estimating a production function that conforms to the law of variable proportions, to the point of decreasing total output.

The convexity assumption inherent in the Farrell technique eliminates that portion of the function over which output decreases with increases in factor utilization. For all practical purposes, this restriction is not severe in that it excludes only those firms that might operate outside the rational range of production.

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Procedure

A random sample was selected from the Idaho Cattlemen's Association membership records. No information was available on the operation system adopted by individual members; thus, stratification by system was not possible. One hundred and fifty questionnaires were mailed to Idaho cattle ranchers. Seventy-eight ranchers responded. In addition to information about output, labor, feed, and animal unit months (AUM); questionnaires also sought calving ratio, weaning ratio, weaning weight and death loss data. Calving ratio, weaning ratio, weaning weight, and death loss information was used to standardize the sample relative to management practices and the physical environment. Forty-eight observations were selected. The final sample included twenty cow-calf operations, seventeen cow-yearling operations and eleven completely integrated operations.

The Farrell and the Farrell-Fieldhouse techniques were used to estimate relative technical efficiency coefficients for sample observations. An inherent conceptual and empirical problem in the Farrell approach is the ambiguous measure of technical efficiency for observations falling outside the cone cod. Bressler illustrates this point and indicates his empirical studies suggest a large proportion of observations fall outside the cone cod (pp. 130–31). Examination of observations in the final study sample concerning feed, labor, and AUM inputs, indicates only 8% of the observations were outside the cone cod. The procedure used to select the final sample may have minimized the management bias relative to the proportions of feed, labor, and AUM unputs utilized by the activities in the sample.

The estimation of the frontier isoquant for the three systems is based on the assumption that observations in the three systems are on different points of the same production function.[1] Timmer examined the effect of technological changes on estimating the frontier isoquant (pp. 128–30). He demonstrates that non-neutral technological change affects the marginal rate of substitution, causing unit isoquants to cross as different frontiers are estimated for different time periods. Given the state of technical knowledge and the inputs used in estimating unit isoquant, the assumption employed in this study is justified.

The method developed by Seitz was used to estimate the efficient unit isoquant and to estimate the technical efficiency ratings of the forty-eight observations in the sample. In the case where economies of scale are important, each activity is represented by a vector $P_j = [S_j Y_{ij}]$, where S_j = scale, Y_{ij} = unit factor utilization (input divided by output), $i = 1, 2 \ldots, m$ inputs, and $j = 1, 2 \ldots,$ 48 activities. Each of the activities in turn furnishes the coefficients of the "right-hand-side" of forty-eight distinct linear programming problems. For example, the linear programming problem for any activity, P_l, selected from the set of the forty-eight activities is defined as

$$\text{(1)} \qquad \max X_o = \sum_{j=1}^{n} X_j,$$

subject to $X_j \geq 0$,

$$\text{(2)} \qquad \sum_{j=1}^{n} X_j\,(P_j - S_l E_1) \leq (P_l - S_l E_1),$$

where X_j = the level of operation of the jth activity; ΣX_j = maximum output that can be achieved from the set of inputs for the jth activity subject to the requirement that the weighted average scale of the activities in the optimum basis is precisely equal to the scale of the jth activity; P_j = a vector equal to $[S_j Y_{ij}]'$; S_j = scale and is a single element or scalar incorporated in the vector of the jth activity; Y_{ij} = input-output ratio; $i = 1, 2, \ldots, n$ inputs; $j = 1, 2, \ldots, n$ activities; P_l = is a selected activity out of the set of forty-eight activities and represented by the vector $[S_l Y_{lj}]'$; and $E_1 = [1.0, 0.0, \ldots, 0.0]'$.

The set of convex combination of the optimum basis defines one hyperplane of the efficient unit isoquant. The technical efficiency given scale (TES) rating of the activity P_l is equal to $1/X_0''$, where X_0'' is the optimum value of the objective function. Upon the solution of the forty-eight linear programming problems, the efficient unit isoquant is completely defined in terms of those activities for which TES = 1.00.

The linear programming problem for the selected activity, P_l, where constant return to scale is assumed is defined as

$$\text{(3)} \qquad \max X_0 = \sum_{j=1}^{n} X_j,$$

subject to $X_j \geq 0$,

$$\text{(4)} \qquad \sum_{j=1}^{n} P_j X_j \leq P_l,$$

where P_j is a vector equal to $[Y_{ij}]'$, and Y_{ij} and X_j are defined as above. The level of technical scale efficiency (TSE) is given by the ratio $1/X_0''$ where X_0'' is the optimum value of the objective function. The complete description of the computational procedures and the Fortran System of the above models is shown by Boles.

The economic and price efficiency ratings for the forty-eight activities were determined using the method described by Seitz. The variables are defined as follows: (*a*) Two measurements of output were considered. Output is expressed in pounds of

[1] The difference between the "frontier" concept presented by Farrell and the "average" concept is that the "frontier" concept defines a production function that expresses maximum product obtainable from the combination of factors at the existing state of technical knowledge (Carlson, pp. 14–15), while the "average" concept defines a production function that is fitted through a series of observations on the firms for output and several inputs. For further discussion of the relative merits of a frontier function and one estimated with averaging techniques, see Aigner and Chu (pp. 826–27).

liveweight production excluding death loss, 20% heifer replacement, and 1% bull replacement but including home-consumption and cull animals. Output is expressed in the value of the product produced.[2] (*b*) Three inputs were used in estimating production efficiency. Johnson and Eckert show that feed constitutes 68%–77% of total cost of beef production depending on the system of operation. All feed items were converted to digestible energy and measured in alfalfa equivalents. Johnson and Eckert show that labor accounts for 4%–7% of total cost of beef production, depending on the system of operation. Labor was measured in manhours and included both family and hired labor. Western ranchers depend on public land grazing for an average of five months a year. Grazing was measured in animal unit months (AUM) and includes grazing on federal, state, and private land. (*c*) Output is used as a measure of scale.[3]

Analysis of Results

Optimal Size

The size distribution of observations in the final sample ranged from 10,600 pounds to 479,700 pounds annual output. The measures of technical, price, and economic scale efficiency relate the efficiency of beef operations of varying size and identify the optimum scale of operation. Relative to other activities in the sample, an operation with annual output of 479,700 pounds has 100% technical, price, and economic scale efficiency ratings. This size of operation is optimal when total product or products' value is used as a measurement of output. The measures of technical, price, and economic efficiency given scale indicate the degree to which inefficiency observed in an operation of a given size is due to level of factor usage, the proportion utilized, or some combination thereof. By accounting for the scale effect, several activities emerged with 100% technical, price, and economic efficiency given scale.[4]

System's Effect

The effect of system on the efficiency coefficients given scale is tested in the following model.[5]

$$(5) \qquad H = \frac{12}{N(N+1)} \sum_{i=1}^{K} \frac{R_i^2}{N_i} - 3(N+1),$$

where H = chi-square with $K - 1$ degrees of freedom, $N = n_1 + n_2 \ldots + n_k$ observations, R_i = the sum of rank in the ith system, $i = 1, 2, \ldots, K$ system.

The computed H-values for the efficiency coefficients given scale, are less than $\chi^2_{2\ \text{d.f.},\ \alpha = 0.05} = 5.99$, indicating no statistically significant difference between the three systems of beef operation with respect to technical, price, and economic efficiency given scale (Araji 1975). Therefore, after the scale effect is accounted for, system of operation does not seem to significantly influence the internal efficiency of beef cattle operation with respect to feed, labor, and AUM inputs.

Implications

The results of this study indicate that after the scale effect is accounted for, the system of operation does not significantly influence the internal efficiency of beef cattle operations with respect to feed, labor, and AUM utilization. Optimum size is estimated at 479,700 pounds of annual liveweight production. Managerial decision to achieve the optimal size of operation through specialization or vertical integration is a function of the fixed cost and external economies associated with each rather than internal efficiency (Araji 1975).

The completely integrated system operating at optimal size has a potential fixed cost saving of $30,164 annually compared to optimal size cow-calf system and $15,971 compared to the cow-yearling system (table 1). Costs associated with transportation and auction market fees from the time the weaner leaves the ranch until it reaches the feedlot are estimated at $12.22 per head (table 2). This cost does not include shrinkage, death loss, and medication associated with the transferring of beef animals. This completely integrated system has an advantage in transportation and handling costs of $4,546 annually, compared to the optimal size cow-calf system, and $1,728 compared to the optimal size cow-yearling system. In general, fixed cost

[2] Since the value of a pound of calf is not equivalent to the value of a pound of yearling, which is not equivalent to the value of a pound of finished beef, standardizing output in terms of the value of the products produced will provide a more uniform unit of measurement. Expressing output in terms of total revenue for the purpose of measuring production efficiency could not be justified theoretically unless the products under consideration have similar demand structures. Prices of calf, yearling, and finished beef are highly correlated and the three beef products have similar demand structures (see Araji 1971).

[3] The prevailing Farrell-Fieldhouse-Seitz model uses output to represent scale. This treatment could underestimate the scale effect and overestimate technical efficiency. However, for the purpose of this study, output is considered the best feasible variable to represent scale.

[4] For complete information on relative efficiency ratings of the forty-eight activities in the sample study, see Araji (1975). Since efficiency coefficient is measured as the difference between the firm's actual output and the efficient isoquant, the efficiency coefficient is a catch-up of many other factors. Two important ones should be noted: (*a*) random disturbances (in the case of this study, the errors are small compared with the variation in efficiencies and for all practical purposes, this bias is negligible [Farrell, p. 263]); and (*b*) management bias (optimum size of beef operation requires managerial input with relatively high education, high economic motivation, high scientific orientation, and low risk aversion (Araji and Finley)). While it is not an easy task to incorporate the human factor in the estimation of production efficiency, the procedure used in the selection of the final sample should have minimized the management bias in estimating efficiency coefficients for the observations in this study.

[5] The distribution of the efficiency coefficients estimated by the Farrell-Fieldhouse technique does not satisfy the normality requirement for the use of parametric statistics to test the effect of system on the efficiency of beef production. The Kruskal-Wallis test is a nonparametric counter-part of one-way analysis of variance and is a useful test when the normality requirement cannot be satisfied (Colquhoun, pp. 191–95).

Table 1. Total Capital Investment and Annual Fixed Cost Associated with the Optimum Size of Beef Cattle Operation by System

System	Optimal Size (lb.)	Number of Animals[a] Unculled	Culled	Cow Unit[b]		Total Capital[c] Investment ($)	Total Annual[d] Fixed Cost ($)	Annual Fixed Cost (¢/lb.)
Cow-Calf	479,700	719	192	995		1,019,875	69,222	14.4
Cow-Yearling	479,700	566	134	791		810,775	55,029	11.4
Completely Integrated	479,700	372	89	524	ranch	537,100	36,454	7.6
					feedlot	19,200	2,604	0.5
						556,300	39,058	8.1

[a] Unculled animal refers to weaner at 400 lb. average weight, yearling at 600 lb. average weight, and finished beef at 1,050 lb. average weight. Culled animals refer to cows and bulls at 1,000 lb. average weight.
[b] Cow-unit includes 20% heifer replacement and 1% bull replacement plus 5% death loss from birth to weaning, 2.3% death loss from weaning to yearling, and 2% death loss in the feedlot. Calving ratio of 98% was used.
[c] Capital investment of $1,025 per cow-unit was used (see Araji 1975, appendix b—table 1). Capital investment of $96 per head for feedlot capacity of 200 head was used (see Araji 1975, appendix B—table 3).
[d] Annual fixed cost of $69.57 per cow-unit was used (see Araji 1975, appendix B—table 2). Annual fixed cost of $7 per head for feedlot is used (see Araji 1975, appendix B—table 4).

Table 2. Transportation and Handling Cost by Class of Beef Animal

Item	Type of Beef Animals: Weaner $/Head	Yearling $/Head	Total $/Head
Transportation[a]	$2.80	$3.64	$ 5.72
Auction[b]	2.40	2.80	5.20
Yardage and feed[b]	0.50	0.80	1.30
Total	$4.98	$7.24	$12.22

Source: Araji 1975.
[a] Average transportation costs in from a random sample of beef cattle operators in Idaho.
[b] Auction fee per head and yardage and feed cost per day per head was obtained from selected auctions in Idaho.

and transportation and handling costs associated with the three systems of beef operation strongly justify vertical integration in beef cattle production. The completely integrated system operating at optimum size has a potential annual net benefit of $34,710 compared to the optimal size cow-calf system and $17,699 compared to similar size cow-yearling systems.

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Incorporating Small Group Activities into Agricultural Economics Classes

Fred C. White and Sherry K. White

Traditional classroom instruction which consists almost entirely of lecturing is often criticized because it relies heavily on passive learning methods and ignores other effective methods which actively involve students. Consequently, there is a need in college classrooms to generate more student participation that will make the subject matter not only more interesting but challenging. Small group activities can help solve the problems that many college instructors encounter. Although small group activities are certainly not new, their limited use in the social sciences indicates that instructors may not be fully aware of the potential applications and effectiveness of these methods. The objectives of this paper are to describe areas in which small group activities may be incorporated into agricultural economics classes and to evaluate their usefulness in supplementing other teaching methods.

Teaching improvement workshops in agricultural economics have emphasized such techniques as television lectures; audiotutorial instruction, including slide sets, films, tape cassettes, etc.; independent study; and computer-assisted instruction (Workshop on the Improvement of Education in Agricultural Economics). Use of small group activities was mentioned in these workshops only in conjunction with computer-assisted instruction. Although the latter methods were considered effective in motivating students, emphasis in describing the techniques was concerned with computer application rather than small group activities. Furthermore, other methods for incorporating small group activities into agricultural economics classes were not explored.

Procedure

Small group activities were incorporated into agricultural economics classes at the University of Georgia during the 1974–75 academic year. These activities were used in classes on aggregate economic analysis and agricultural policy; they are junior level, required courses for agricultural economics majors but are also taken by other majors. Class size ranged from twenty to thirty students. Each small group contained from three to six students but size could be varied as appropriate.

To evaluate the effectiveness of small group activities, test scores for students in these classes were compared to scores of previous students. In addition, students were asked to complete a questionnaire evaluating these activities. Basic information on cumulative grade point average and major was obtained for each student in order to determine which type of student would show favorable response to this teaching method.

Small group activities can be used in various forms to teach application of economic principles. More specifically, the class may be divided into groups to solve problems, gather and analyze information, or discuss ideas. Each of these activities is described below.

Problem-Solving Groups

The instructor first presented basic economic principles that students were expected to use. Since solving problems requires a capacity to discern the problem and identify alternative solutions, problem solving provided an opportunity to apply economic principles. For selected problems, students were divided into small groups in anticipation that discussion with other students would help develop a strategy for problem solving. When less able students were temporarily lost, this approach provided the instructor an opportunity to work with these students while other groups worked independently of the instructor. The instructor closely monitored student progress and acquired immediate feedback from them. In an aggregate economic analysis class, students analyzed problems dealing with unemployment, recession, and inflation. The small groups identified potential problem situations and then attempted to formulate policies to solve these problems.

Resource Groups

In some instances, larger problems can best be analyzed by considering individual components. The class first participated in dissecting such problems into workable components. Then, small groups which had access to resource materials (through the instructor, library, etc.) worked on separate but related parts of a larger problem. After each small group researched its particular part, the information was fed

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back into the total group in a synthesis session to reassemble the components.

In an agricultural policy class, students analyzed a questionnaire obtained from a mail survey of Georgia farmers. The completed questionnaires supplied information on farmers' problems and their perceptions of these problems. The class was divided into groups to cross-classify farm problems by age of operators, size of operation, and region of the state. Each group was responsible for analyzing one of these areas and for summarizing the results. A fourth group was responsible for developing a completed manuscript from the contributions of other groups. Although the study was designed to give students a better understanding of farm problems, it resulted in a research publication that also provided useful information for agricultural and governmental leaders.

In another application of this approach, students were assigned the problem of analyzing a national land use policy. Each group assumed identity of some special interest group, e.g., agriculture, forestry, mining, environmental agencies, local government, or state government. Using library materials, including Congressional hearings, students were to determine what their special interest group wanted from a national land use policy. Based on outside resources, the groups expressed different perspectives for land use policy to the class. Then the class developed a general outline for a land use policy that would integrate diverse social viewpoints. This method showed students how policy evolves and the need to mesh and compromise before an answer is developed.

Discussion Groups

Discussion classes primarily involved an interchange of ideas and knowledge among groups of students, with active participation by the instructor. In this type of group, students researched an assignment and discussed the topic informally with the entire class. However, prior research was not necessary for effectiveness; an informal debate could result by dividing the class into debating teams. Discussions were used to focus on attitudes of students and to allow them to critically evaluate their own attitudes by evaluating others' opinions. In addition, this activity appeared useful as a review at the end of a unit.

All topics are not equally well suited for small group discussion. Topics which require the student to acquire fairly straightforward information may be best suited for lecturing, reading, or other modern teaching techniques (Beard). However, other issues which are more difficult to resolve may be profitably explored through discussion groups.

Evaluation

Small group activities were evaluated with respect to course coverage, motivation, development of communication skills, interpersonal relationships, and instructor's responsibility. Also, attention was focused on student performance and student response to this method.

Small group activities did not greatly alter coverage of material during the experiment, because these activities were used to supplement other teaching techniques. However, these methods appear appropriate for an in-depth coverage of material rather than breadth of coverage. Since each student, as a group member, actively investigated some topics in detail, he became much more familiar with these topics.

Use of small groups provides the student with a variety of learning methods, an opportunity to actively participate in the learning process, and a chance to work with other class members. In most cases, these activities created an environment of healthy competition among the small groups, which stimulated student involvement.

In a recent survey of businesses and government agencies which employ agricultural graduates, employers repeatedly suggested that college graduates needed improved communication skills (University of Georgia). Students often have limited opportunities to develop these skills. However, in discussion groups, students must formulate and organize their ideas on a specific subject, express their ideas verbally, and evaluate other students' opinions. Such a dialogue fosters the development of critical thinking and oral communication skills. Furthermore, problem-solving and resource groups can be used to improve writing skills.

Dubin and Taveggia report that learning is considered an outcome of interpersonal activity. Small group activities strengthen both student-teacher and student-student relationships. With these activities, students recognize that the instructor's primary role is to facilitate learning, not simply to dispense information. Thus, the instructor has a better rapport with the students. Moreover, small group activities differ from general discussion classes which involve only student-teacher interchange. In the student-teacher interchange some students may dominate the class discussion, while others are reluctant to participate. Students have a greater opportunity to participate when the class is divided into smaller groups, and many will share their ideas with two or three class members but not with the entire class. Furthermore, students are eager to help one another and working together helps create a class identity.

In general, using small group activities does not alter the instructor's responsibility for establishing course objectives and a timetable for covering the material. Their use allows the instructor to employ multiple teaching techniques which Kendrick cites as a requirement for effective teaching. Thus, small group activities aid the instructor in creating an environment in which learning can take place. By working with small groups, the instructor can ensure that everyone is participating in problem solv-

Table 1. Effect of Small Group Activities on Student Performance

	Regression Results[a]	
Dependent variable: Test score		
Constant	−10.93	−10.98
Independent variables:		
Average score on previous tests	1.02 (0.13)	1.02 (0.16)
Dummy variables for small group activities		
All students	4.38 (2.41)	
Students with above average grade on previous tests		4.41 (3.69)
Students with below average grade on previous tests		4.37 (3.00)
R^2	0.56	0.56

[a] Standard error is given in parentheses.

ing and can aid those students who otherwise display little interest in the material or who would have difficulty with the assignment. Other students who understand the material could be moving at a faster pace, while working independently of the instructor.

When students are actively involved in small groups, the instructor devotes less time to formally structured presentations. However, this method requires that the instructor be well prepared and have a thorough knowledge of the subject matter. In addition, the instructor must be able to handle many situations to provide guidance and encouragement to students.

Student Performance

Although students applied economic principles in small group activities, each student was held individually accountable for achieving course objectives. Thus, test scores could be used to measure the impact of these activities on student performance. Test scores for those students who had participated in small group activities were compared with scores of students in other classes taught by the same instructor but without the benefit of small group activities. Data from a sample of sixty-two students, equally divided between classes with small group activities and without, were used in a regression analysis to measure differences in student performance resulting from these activities. The two classes completed similar exams over material for which only one class had used small group activities. These individual test scores were used as the dependent variable in the regression analysis. Since it was necessary to correct for differences in student ability, each student's average score on previous tests was used as an independent variable. A dummy variable whose value was one for students in the class with small group activities and zero, otherwise, was the other independent variable.

The regression results are shown in table 1. The principal result of this analysis indicates that, on the average, students who participated in small group activities scored 4.38 percentage points higher than others. Further analysis using two dummy variables to divide the sixty-two observations into three groups indicated that the advantage of small group activities applied equally to students regardless of ability.[1] Participation in small group activities raised the expected test score 4.41 percentage points for students with above average scores on previous tests and 4.37 percentage points for students with below average scores.

These regression results are not definitive evidence on the merits of small group activities, but, in general, it was felt that students were better trained after applying principles they had learned. Other applications of small groups may not be evaluated in such a straightforward manner. For example, these methods provide opportunities for students to study certain topics in greater detail. Thus, with the implementation of small group activities, course coverage may vary somewhat from previous offerings.

Student Response

In addition to informal critiques, students were asked to complete a questionnaire on the effectiveness of small group activities. The questionnaire also included questions on the student's academic major and cumulative grade point average in order to identify which type of student favored these activities. In general, student reaction to small group activities was favorable. Responses from the

[1] This regression equation included two dummy variables. The first dummy variable had a value of one for students in the class with small group activities who had an above average mean test score on previous tests and a value of zero otherwise. The second dummy variable had a value of one for students in the class with small group activities who had a below average mean test score on previous tests and a value of zero otherwise.

Table 2. Student Reaction to Small Group Activities

Student Characteristics	Student Reaction: Strongly Favor	Favor	Indifferent, Object, Strongly Object	Number of Students
	.... %			
Cúmulative grade point average:				
Less than 2.4	50	50	0	8
2.4 to 2.8	50	50	0	14
2.8 to 3.2	63	37	0	8
Greater than 3.2	75	25	0	8
Major:				
Agricultural economics	57	43	0	23
Other	53	47	0	15

thirty-eight students from two classes who completed the anonymous questionnaire on these activities are presented in table 2. The responses of students with less than a 2.8 grade point average were equally divided between strongly favorable and favorable, while students with higher grade point averages tended to be strongly in favor of these activities. Over half of the responses were strongly favorable for both agricultural economics majors and other majors (table 2).

In addition, students suggested specific ways that the method was beneficial. Some students indicated that they learned more because they were involved in the research and were able to defend a viewpoint. Furthermore, some recognized that they had learned because of exposure to various viewpoints. Some said it created a more relaxed atmosphere and helped them to interact better with other students. Competition was another key comment made by students; the healthy competition between small groups stimulated active participation. Efficient use of class time was also mentioned by several students.

Limitations

Small group activities involve instructor's time and effort. To the extent that these activities are well planned and executed, they may involve more time in planning than would the lecture technique. However, the time requirement is highly variable depending on the activity. The instructor's leadership role in the classroom is expanded to include developing and directing group activities. To make sure that these activities proceed in the right direction, the instructor must remain alert to each group's progress and problems.

These activities are time consuming. Students are involved in a thorough examination of economic principles being applied to a rather limited problem. Thus, this method may be inefficient when a wide range of material must be covered in a specified period of time.

Class size may be a problem. The class may be too large for the instructor to successfully coordinate all groups. If the class is very small, it may not be necessary to use small groups, because there is more freedom to develop interpersonal relationships.

Conclusions

Small group activities are particularly useful in giving students an opportunity to apply economic principles. Using these activities as supplements to more widely used teaching techniques would provide welcomed variety to students, as well as a vehicle for instructors to maintain contact with individual students. These methods can be used in agricultural economics classes to improve both problem-solving skills and communication skills. Students learn by doing, and these activities provide opportunities for greater student involvement and participation. Student performance resulting from these activities and students' comments helped to substantiate our belief that small group activities have a place in the college classroom.

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Participation by AAEA Membership in the 1974 Election

Barbara J. Redman and John C. Redman

The membership of the American Agricultural Economics Association is widely distributed throughout the world. In the United States, most members are affiliated with the land grant college system or the U.S. Department of Agriculture. The purpose here is to analyze member participation in the 1974 election for president and directors of the AAEA and to determine if affiliation with a land grant institution influences participation and if this participation varies significantly by region.

In accordance with the Bylaws, data are kept on the sending and return of ballots by qualified (paid) members. Also, data on total membership (unpaid and paid) are available in zip code order. This facilitated further sorting into cities in which land grant universities are located and for the rest of the state. Also, Canadian and foreign categories were established.

Slightly more than two-fifths of the individuals who were members in February 1974 voted; about 71% paid dues by April 1 and 58% of those paid returned a ballot (table 1). Less than one-half of the U.S. members in February made the necessary effort and had their vote registered.[1]

To determine if any regional differences in the United States exist, seven regions were arbitrarily delineated, except Kentucky was included in the South (see Redman, p. 145, map), and data were arranged accordingly (table 2). The variance test for homogeneity of the binomial distribution (Snedecor and Cochran, p. 240) showed no significant differences among regions overall, whether using either the percentages paid or the percentages voting.

A test was also made to determine if land grant status had a significant effect on voting. The Washington, D.C. area was omitted from the analysis. The close proximity of Washington to the University of Maryland and the non–land grant areas of Maryland and Virginia made the problem in classifying land grant cities and the rest of the state too great. However, the omission probably did not affect results greatly, since the overall voting in the Washington area did not define either extreme.

The proportions of voting members were calculated for each land grant university city and the rest of the state and grouped into regions, excluding the Washington, D.C. area states (table 3). A two-way analysis of proportions (Snedecor and Cochran, pp. 243–47) was used, which has the added advantage of separating the effects of regional and land grant university influence and testing for both simultaneously.

The proportions p_{ij} were regarded as normally distributed variables with variance

$$\frac{p_{ij}\,q_{ij}}{n_{ij}},$$

with p referring to the proportion of voting members to eligible (paid) members, q to the proportion of eligible members who did not vote, i to the region, j to the land grant status and n to the eligible (paid) members. The proportions and differences in the analysis were weighted inversely as the variances.

One of the (null) hypotheses involved in the two-way analysis was that the proportions of voting members would be the same regardless of land grant university status. Land grant university influence might be expected to be significant as those members tend to be more active generally in

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[1] Ballots were mailed to a total of 2,827 qualified members, which exceeded those qualified in 1973 by 757, and 58.37% returned their ballots as compared to 55.75% in 1973. No doubt much of this increase can be attributed to the fact that in February each unpaid member was sent a "Final Notice to Maintain Eligibility for Voting."

Table 1. Total AAEA Membership and Voting Response, 1974

Category	United States	Canada	Other	Total
Total membership (February)	3154	302	531	3987
Total paid by April 1 and sent ballot	2401	178	248	2827
Percent paid	76.13	58.94	46.70	70.90
Percent of eligible voted	63.93	40.45	17.34	58.37
Percent of membership voted	48.66	23.84	8.10	41.38

Table 2. Regional Distribution of U.S. AAEA Members and Voting Response, 1974

Region	Total Members	Paid Members	Voting Members	% Paid	% Voting
New England	344	264	180	76.74	68.18
Washington, D.C. area	635	498	308	78.43	61.85
South	492	366	239	74.39	65.30
Midwest	838	636	408	75.89	64.15
Plains	319	241	150	75.55	62.24
Mountain	191	146	87	76.44	59.59
Pacific	335	250	163	74.63	64.43
Total	3154	2401	1535	76.13	63.93

Table 3. Observed Proportions in Percentage Terms

Region	Land Grant City	Rest of State
New England	74.286	61.290
South	71.315	53.571
Midwest	70.449	51.643
Plains	62.712	60.938
Mountain	62.857	51.219
Pacific	72.535	55.556
Mean	69.607	54.873

the usual professional activities, especially publishing in the *Journal*. This perhaps is explained by the concentration of professionals, which facilitates research, exchange of ideas, peer pressure, etc. One could logically expect this professional activity and interest to extend to voting in election of officers of the professional society. The extremely strong land grant influence which emerged may dwarf the regional influences so as to hide the latter effect in the homogeneity test using total data.

As no significant differences among regions were found in total data using the variance test for homogeneity of the binomial distribution, there had appeared to be no a priori reason to expect any when using the analysis of proportions on the further regional breakdown according to land grant city and the rest of the state. However, there was a significant difference among regions (table 4) under this second test which isolated regional and land grant university effects.

It may also be argued that the centers of the greatest agricultural economic activity would have

Table 4. Z Values for Main Effects in Two-Way Analysis of Proportions

Land grant institutions vs. rest of state	$Z = 6.4512^a$
Regions, combined effects	$= 5.1484^a$
Regions, land grant cities only	$= 4.2533^a$
Regions, rest of state only	$= 2.9009^a$

[a] Significant at $\alpha = 0.05$.

Table 5. Z Values for Individual Regions

Region (versus all other regions)	Land Grant Cities Only	Rest of State Only
New England	2.5799[a]	2.3090[a]
Mountain	2.9290[b]	1.2629
Plains	3.5890[b]	1.7792[c]
Pacific	1.9230[c]	1.3531
South	1.8774[c]	1.3593
Midwest	2.0766[a]	1.9190[d]

[a] Significantly higher at $\alpha = 0.05$.
[b] Significantly lower at $\alpha = 0.05$.
[c] Significantly higher at $\alpha = 0.10$.
[d] Significantly lower at $\alpha = 0.10$.

the greatest participation in the professional society. Further analysis of proportions voting to determine which regions account for the main effect observed in table 4 do not support this fully (table 5). Differences and variances were calculated for each region versus each remaining region within each land grant college status classification and weighted and combined to form the Z value for each region. In the land grant analysis, the New England, Pacific, South, and Midwest regions resulted in significantly higher Z values, and Mountain and Plains regions were significantly lower. For the non–land grant areas, New England was significantly higher at the 5% level. The Midwest non–land grant participation was significantly lower at the 10% level.

Some plausible explanations could be suggested as to why the regional significances occurred. The New England area has several land grant universities, each serving a smaller area and thereby offering better communications and cohesiveness among all members in the area. The reverse may be proposed for the Mountain area's low participation. This, however, does not explain the participation in the Plains and Midwest. One relevant point could be the small difference in proportions between the land grant and non–land grant activity in the Plains. In addition, the location of election candidates may influence their respective regions' participation.

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Profiles of Heads of Departments of Agricultural Economics in the United States

Dilip Pendse

In recent years, the *Journal* has enlightened its readers on such subjects as the spatial distribution of membership in the American Agricultural Economics Association, the institutional affiliation of authors contributing to the *Journal*, and its use as a reference in research (Finley and Barger, Holland and Redman, Redman). Information about persons who direct departments of agricultural economics in the major universities is one subject that has received little attention in the *Journal*. Although department heads hold positions of substantial responsibility, little information is available about their professional and academic achievements, their institutional affiliations, their areas of specialization, and the like. The purpose of this note is to provide a group profile of the persons who headed the fifty departments of agricultural economics in the fifty major U.S. universities as of August 1, 1975.[1]

The information reported is based mainly on the *Handbook-Directory* of the members of the AAEA published in 1966 and 1972. Some additional data concerning academic and professional achievements, publications, and awards were gathered from issues of the *Journal* published from 1950 to 1974. Reliance on secondary data has naturally put severe limitations on the kind and amount of information provided in this note. Nonetheless, the information presented here should be of interest to AAEA members.

No department head is a woman, and except for one born in Germany, all were born in the United States, in twenty-eight states. The largest number, fifteen, come from the states in the western North Central region; the states in the North Central and the South Central regions number eight each; the states in the North Atlantic, the South Atlantic, and the Far West number six each.

Data on the institutions awarding Ph.D.'s to department heads and their approximate age are presented in table 1. The table shows that all department heads have earned the Ph.D., awarded by seventeen institutions, mostly land grant universities.[2] The University of Minnesota (8), the University of California (6), Iowa State University (4), and the University of Wisconsin (4) have awarded the Ph.D. to 44% of the department heads. This is likely related to a number of factors including, but not limited to, the size of the department, the diversity of graduate programs, the number of Ph.D.'s awarded each year, and the "prestige" attached to graduates of particular institutions.

Sixty percent of the department heads were born prior to 1930. The youngest department head is thirty-five years of age, while the oldest is sixty. The majority of them are forty-five years of age or over. Data presented in table 1 suggest the number of vacancies that may occur in department head positions in the next few years. Data presented in table 2 indicate that all department heads received the Ph.D. between 1949 and 1969, 56% during the 1949–59 period and 44% during the 1960–69 period.

A simple approach was taken to assess professional and academic achievements of department heads. First, all the articles, notes, discussions, and reviews authored or coauthored by department heads in the *Journal* during the twenty-five year period from 1950 to 1974 were surveyed. Second, data were gathered on department heads who had been either elected president of the AAEA, worked as the editor of the *Journal*, won AAEA awards for excellence in teaching, extension work, and published research, or were recognized for directing award-winning M.S. or Ph.D. theses. Third, data were obtained on department heads whose scholarly achievements have been recognized in the Who's Who directories.

Department heads have authored or coauthored a total of 184 articles (including reviews, notes, and discussions) in the *Journal* during the 1950–74 period (table 2). As table 2 indicates, thirteen or 26% of the department heads have not authored a single article in the *Journal* in the past twenty-five years. The largest proportion of nonauthors belong to the group of department heads who received their Ph.D.'s in 1965 or later years; the smallest

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[1] Although the list of department heads in my possession contains names of fifty-four persons (thirty-two "heads" and twenty-two "chairmen"), data on four department heads were not available in any of the *Handbook-Directories* of the AAEA members or in the Who's Who directories.

[2] Presumably these Ph.D.'s are in the fields of economics or agricultural economics. It is impossible to identify these degrees since the *Handbook-Directory* of AAEA members does not indicate in what field the Ph.D. was obtained.

Table 1. Age Composition and Institutions Awarding Ph.D.'s to Heads of Departments of Agricultural Economics

Institutions Awarding the Ph.D.	Year of Birth 1915–19	1920–24	1925–29	1930–34	1935–40	Total
University of Minnesota	3	2	1	1	1	8
University of California	1	2	—	3	—	6
Iowa State University	—	2	1	1	—	4
University of Wisconsin	—	1	1	1	1	4
Cornell University	—	—	1	1	1	3
University of Illinois	1	1	—	1	—	3
North Carolina State University	—	—	2	—	1	3
Michigan State University	—	2	1	—	—	3
Oklahoma State University	—	—	1	1	1	3
Purdue University	—	1	—	1	—	2
University of Missouri	1	—	1	—	—	2
University of Connecticut	—	—	—	2	—	2
Harvard University	1	—	1	—	—	2
University of Chicago	—	—	1	1	—	2
Oregon State University	—	—	—	1	—	1
University of Maryland	—	1	—	—	—	1
Ohio State University	—	—	—	1	—	1
Total	7	12	11	15	5	50

proportion belong to those who earned Ph.D.'s during 1949–54. Seventy-one percent of the *Journal* articles authored by the department heads are by those who obtained their Ph.D.'s during the 1950s. Furthermore, 46% of the department heads with some *Journal* publications have contributed less than five articles per person in the past twenty-five years. Four department heads have authored fifty-four articles in the *Journal* (29% of the total) during the same time period.[3] Of those who have authored articles in the *Journal,* the 1949–54 group has had on the average 6.5 *Journal* articles in the past twenty-five years, as compared with 5.3 per person from the 1955–59 group, 4.1 per person from the 1960–64 group, and 2.4 per person from the 1965–69 group.

Only one head has been president of the AAEA; only one has been editor of the *Journal* (for two years). One department head has been a three-time cowinner of the AAEA published research award, one has won the AAEA distinguished teacher award, and three have been recognized for directing the AAEA award-winning M.S. theses.

Twenty-four or 48% of the department heads are recognized in at least one of the Who's Who directories. Nineteen are listed in the *American Men of Science,* eleven in *Who's Who in America,* two in the *Directory of American Scholars,* one in *Leaders in Education,* one in *International Who's Who* (Europa), and six in other directories. Of the twenty-four department heads recognized in such directories, thirteen are listed in one directory, eight in two directories, two in three directories, and one in five directories.

A summary of the subject specializations of the department heads presented in table 3 reveals that there are four areas of interest, given in order of preference: (*a*) agricultural marketing; (*b*) agricultural policy; (*c*) land and water economics, conservation, and development, and (*d*) farm management and production economics. One can relate the importance of these areas to the era in which the

[3] In the context of the *Journal* articles authored by department heads, only one department head is included in the Finley-Barger list of the thirty-eight authors most cited as referenced in the *Journal* articles during 1959–68.

Table 2. Year Ph.D. Granted and *Journal* Articles Authored by Heads of Departments of Agricultural Economics, 1950–74

Year Ph.D. Granted	Heads of Departments	*Journal* Articles Authored by Department Heads 1950–54	1955–59	1960–64	1964–69	1969–74	Total Articles	Department Heads with No *Journal* Articles	Average Number of *Journal* Articles Per Author
1949–54	15	7	23	24	12	12	78	3	6.5
1955–59	13	—	17	16	10	10	53	3	5.3
1960–64	13	—	1	12	16	12	41	3	4.1
1965–69	9	—	—	2	8	2	12	4	2.4
Total	50	7	41	54	46	36	184	13	5.0

Table 3. Subject Specializations of Heads of Departments of Agricultural Economics

Subject	Preference			
	1	2	3	4
Agricultural marketing	14	3	3	2
Agricultural policy	8	12	4	3
Land and water economics, conservation, and development	8	2	4	4
Farm management and production economics	7	9	1	1
Agricultural finance and credit	5	4	2	—
Economic development	3	5	9	7
General economic theory	2	2	1	2
World agricultural production and trade	1	3	1	2
Agricultural prices	1	1	6	1
Econometrics	1	—	—	3
Statistics and methodology	—	3	5	2
Economics of food and nutrition	—	—	2	—

individuals received their graduate training. Few department heads have specialized in the areas of statistics and methodology, econometrics, or economics of food and nutrition.

Three-fourths of the department heads are members of some professional society other than the AAEA. On the average, department heads hold membership in two professional societies in addition to their AAEA membership. Most, but not all, heads are members of the regional agricultural economics societies, the Southern Agricultural Economics Association (14), the Western Agricultural Economics Association (11), and the North Eastern Agricultural Economics Council (5). Less than one-third of the department heads are members of the American Economic Association. Seven are members of the Association of Americans for the Advancement of Science. Only one is a member of both the American Statistical Association and the Econometric Society.

One question often raised about a department head is how did he obtain the administrative position? Did he move up "through the ranks" at a given school or did he move into the position from another institution? A close scrutiny of the data provided in the *Handbook-Directory* reveals that 66% of the department heads have been promoted "through the ranks" and the remaining 34% moved into the position from another institution.

Department heads hold distinctive positions of considerable responsibility. Some have risen to become deans, while others have become presidents of universities. Some have held high government positions,[4] while others have re-entered the ranks of the faculty by preference or because of the rotating nature of the chairmanship. Although a group profile of fifty department heads presented here provides some new statistics, many questions remain unanswered. For example, what are department heads' goals and roles? What are the job requirements? What kind of administrative, research, and teaching duties do department heads perform? What kind of satisfaction do they derive from the position? How long would they recommend a person remain as a department head? What kind of conflicts arise in the line of duty between professional goals and administrative roles? Such questions have been studied by Heimler; Hill and French; McLaughlin, Montgomery, and Malpass; Satlow; and Smith.

[4] For example, Earl Butz, Secretary of Agriculture in the Ford Administration, is a former chairman of the Department of Agricultural Economics at Purdue University.

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Publications

Books Reviewed

Bowers, Patricia F. *Private Choice and Public Welfare: The Economics of Public Goods*. Hinsdale, Ill.: Dryden Press, 1974, xiv + 527 pp., price unknown.

This is a truly ambitious book. It attempts to present, in a manner accessible to advanced undergraduates and beginning graduate students, a complete, coherent, and integrated account of the role of the public sector in the United States. In this one book, the reader is exposed to the broad subjects of public finance, modern welfare economics, the theory of social (or collective) choice, project evaluation techniques, static macroeconomics, macrodynamics, and the theory of stabilization policy. Specific topics include, for example, the market and efficiency, externality and public goods, the rationale for having a public sector, the optimal mix of public and private output and the optimal size of government, tax-subsidy schemes, marginal cost pricing, government influence on private choices, budget strategy, benefit-cost analysis, the economics of defense and housing, public sector budgets and fiscal incidence, the impact of government policy on saving, investment and labor market participation, employment policy, prices and incomes policy, automatic stabilizers and discretionary policy, and growth policy. Public sector activities at the federal, state, and local levels are considered as a system and the mutual influences of policies pursued at each level of government are highlighted. It is, as I have said, an ambitious book.

A subsidiary aim is to introduce the reader to the huge volume of recent literature in each of these areas. Important theoretical contributions are highlighted and applied to the analysis of specific issues. Empirical findings from the literature and government statistics are introduced, as appropriate. The economic behavior of the public sector is described, explained, analyzed, and evaluated. Mathematical analyses are presented along with verbal analyses. This reviewer has not seen another book which undertakes such a comprehensive analysis of the economics of the public sector.

It is assumed that the public sector in a market economy has four basic goals: (*a*) the provision of an environment which maximizes the scope of individual choice, (*b*) the provision of optimum [sic] levels of living, (*c*) maintenance of the optimum [sic] rate of economic growth, and (*d*) the equitable distribution of income. The integrating, analytical concept is that of public goods. Income redistribution, economic stabilization, and most everything a government provides is said to be a public good. (Bowers's definition of "public good" would seem unsatisfactory to theoretical purists, for whom the term has a more specific meaning. Not everything provided by the public sector is a public good.) The welfare concepts of Pareto-optimality and second-best optima are applied, more broadly than is usual, to evaluate not only the allocative and distributive activities of government but also macroeconomic stabilization activities.

Given the ambitious and eminently worthy goals the author has set for herself, it would be delightful to be able to praise the book wholeheartedly. However, this is a very imperfect book. It is quite poorly written, in a style which is verbose and frequently imprecise. It reads like a manuscript in search of a rigorous and fastidious editor. There are incoherent sentences, typographical errors, confusing diagrams, and diagrams which are in error. More damning, perhaps, is that the sloppiness in presentation sometimes extends to analysis. Ideas, concepts, and terminology are applied loosely. "Efficient" is often used where "effective" or "efficacious" would be more appropriate. Bowers does not seem to understand that "second-best solution" has precise meaning (the optimal feasible solution in circumstances where Pareto-efficiency is unattainable) and cannot be used to describe just any non-Pareto-efficient solution which seems workable. The concept of externality is introduced in a legal vacuum. The analysis presented on p. 97 does not prove, as claimed, that simple majority voting minimizes social costs; all it suggests is that some majority short of unanimity will probably do it.

Bowers seems sometimes to be a little too willing to accept that existing government activities are justified, in the sense that they at least make the best of a difficult situation. Regulation in externality situations, for example, is accepted with little consideration of the alternatives provided by market solutions and tax-subsidy schemes. The sentence, "[i]n fact [defense contractors] and the government work together as partners for the purpose of attaining national goals" (p. 234) seems to exhibit a touching naivete. A major omission is that the internal efficiency of government is not considered. How much of the expenditures for particular programs reach their target populations, and how much is absorbed in administrative expenses, transactions costs, etc.?

Nevertheless, there is a good deal of value in this book. The concept of an integrated analysis of the economic activities of the public sector has much to recommend it, and much of Bowers's material is adequate and competent. A major contribution is made by her several detailed examples of the interactions between different policies pursued for different purposes. The inconsistencies between targets make it difficult for government to avoid

working at cross-purposes with itself, and the student needs to understand this.

One hopes this book will appear in a second edition, in which the sloppiness and imprecision of the current edition will be eliminated. Then, Bowers's admirable concept may be executed with the clarity and rigor it deserves.

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Lindholm, Richard W. *Property Taxation and the Finance of Education* (TRED-7). Madison: University of Wisconsin Press, 1974, 323 pp., $10.00.

This book consists of the papers and discussion of a conference sponsored by the Committee on Taxation, Resources, and Economic Development at the University of Wisconsin. It includes contributions by distinguished researchers and leaders in the fields of economics and public finance. The purpose of the book is to examine education finance through theoretical economic analyses, empirical studies, and legal considerations.

The book first provides background material related to historical, legal, and economic issues. A brief historical perspective on financing education in the United States shows almost total dependency on local financing in the nineteenth century. As state governments recognized that some school districts lacked the taxable capacity to provide acceptable educational programs, state aid was combined with local taxation in the form of equalization programs. However, substantial disparities in educational opportunities exist among geographic regions even with increased federal and state aid. Another major criticism of the present system of education finance concerns the disparity in tax burden among local jurisdictions. Much of this criticism is focused on the property tax because it accounts for most local government revenue. Inequities in tax burdens exist partially because of an unequal distribution of industrial and commercial wealth across states. Tax inequities may also arise because of differences in community needs for taxes.

Disparities in educational opportunity and tax burdens are increasingly under scrutiny. Landmark court decisions call for substantial reform in education finance: to meet the "thorough education" standard required by New Jersey's constitution or to eliminate the fiscal disparities as required in California. The book contains several articles which explore proposed alternatives to the present finance system, including expansion of the state role within the present system, redistricting, full state funding, power equalizing, coordinated tax base sharing, and tuition grants. Power equalizing establishes a relationship between the tax rate levied and the expenditure per pupil permitted the district. Any deficiency in revenue for a given tax rate would be made up by the state so the district would achieve its permitted expenditure. With coordinated tax base sharing, states would establish a school fund to which surplus districts (based on desired tax rate and permitted revenue) would contribute and on which deficit districts would draw. Tuition grants provide publicly funded vouchers with which parents would pay some or all of their children's education.

Removal of tax impediments to equality of educational opportunity entails greater state administration of tax systems as well as increased efforts to remove tax regressivity. Several articles examine the implications of shifting tax burdens from the property tax onto other state taxes. Although heavy reliance on other taxes may create new imbalances, many possibilities for preventing such imbalances were considered. The primary reason for not abandoning the property tax as a source of revenue for education is the magnitude of new revenue that would have to be generated. Furthermore, windfall gains, which would accrue to property owners if the property tax was substantially reduced, would be generally unacceptable to the public.

Following previous books in the TRED series, this book repeatedly endorses the land tax. It is pointed out that a statewide land tax could generate revenue levels that would be comparable to the property tax and would also avoid windfall gains to some property owners. A major reason for shifting to a land tax over the property tax is that the land tax is economically neutral, while taxes on improvements are shifted to consumers, renters, etc. Although the value of land is largely created by society, land values are enjoyed by the owner and land taxes are paid by the owner. Thus, increases in the value of land which are created by society can be taxed away without decreasing general economic well-being. The unique nature of land provides a link between a tax on land and the support of education: there are elements of externalities in both the benefits of public education and the value of land.

The authors claim that alternatives to the property tax, particularly the land tax, would avoid economic distortions created by the present system of finance. They fail to measure the magnitude of the present distortions. Thus, it is difficult to properly assess the need for a complete shift away from the property tax. Also, the idea of a land tax has been popular to economists since Henry George proposed the tax, but it has been politically unacceptable. The authors fail to come to grips with this problem. Since it is doubtful that the property tax will be substantially reduced, further attention should have been focused on implications of modifying the present property tax system.

It becomes clear from reading this book that an evaluation of educational finance reform should consider the provision of all public services, not simply education. Thus, use of the local property tax to finance education cannot be considered inde-

pendently of the base's other noneducational demands and alternative nonproperty tax sources which substitute for the property taxes.

This book will be of interest and assistance to scholars in economics and public finance and to legislators, government officials, and others concerned with the role of the property tax in school finance. A major strength of the book is its breadth of coverage of alternative methods to finance education, with many excellent case studies for selected states and metropolitan areas. These analyses considered the incidence of various revenue sources and the relation of taxes paid to benefits received from education. Economic efficiency implications of the alternative tax proposals were also explored, although in less detail. On the negative side, the articles are loosely connected and sometimes repetitious.

Fred C. White
University of Georgia-Athens

Osofsky, Stephen. ***Soviet Agricultural Policy—Toward the Abolition of Collective Farms.*** **New York: Praeger Publishers, 1974, xi + 300 pp., $20.00.**

This is an unusual offering in policy literature. It is customary in policy to report a study of what is or has been and why. This book has this fare, too, but more. It lays out a convincing case that the viability of governments of the Soviet Union have and do hinge substantially on the course of events in the agricultural sector. In fact, it may well sketch a predictive scenario of the future. Reading along, one begins to feel the very pulse of the Soviet leadership as it grapples with an alien environment for agriculture, with unfulfilled food production plans, the troublesome kolkhoz (collective farms) as a misfit in Soviet ideology, and reconciling the propensities of the Russian peasant with the social needs of the state.

Osofsky picks up the drama. "Just as Khrushchev criticized the then state of agriculture and, by implication, his predecessor, Stalin, while announcing a 'new deal,' so did Brezhnev promise a 'new deal' for agriculture, and with much less euphemizing" (pp. 12–13). "Matskevich had been ousted by Khrushchev as Minister of Agriculture in 1960 after serving in that post since 1955. In 1960 the crop was again bad. But after Khrushchev's fall, Matskevich was reappointed USSR Minister of Agriculture in 1965 and held that post till now" (p. 240). Within six months after the famous U.S. grain sale to Russia in 1972, *Pravda* announced on its back page the dismissal of Matskevich as Minister of Agriculture, and on its front page the succession of Poliansky to that post. "It was the grain failure of 1972 that did him in, requiring as it did an offering on the altar of public humiliation."

The author continues, "If the upswing of 1973 proves ephemeral and the failures of 1972 are soon repeated, requiring grain imports on the scale of 1972, then Poliansky figures to be cast down in disgrace so as to deflect criticism away from Brezhnev. Poliansky is in a most unenviable position" (p. 242). "The Soviet leaders simply refuse to face the bedrock issues involved, and the price they will continue to pay for this is periodic grain and meat crises and a politically embarrassing dependence upon imports. Brezhnev has stumbled, just as Khrushchev did, on the seemingly intractable problem of agriculture. . . . Perhaps more than any other single domestic issue, agricultural performance will be a decisive one for Brezhnev's political future" (p. 248). With ink hardly dry on the news releases about another massive grain purchase, one waits for the next episode in the serial.

Soviet Agricultural Policy fits more the tradition of political economy found in the rich heritage of the history of economic thought than it does contemporary economics. Be that as it may, it can be a valuable reference to the policy student and teacher who explore increasingly the international dimension of agricultural policy. It may well be the best available source for contemporary Russian policy. Certainly, it supplies the most elaborate bibliography.

Osofsky sets the theme early, "The purpose of this study is to probe for the major problem areas in the kolkhoz sector rather than in Soviet agriculture as a whole, although in many cases the problems overlap and are inextricably bound together. . . . The kolkhoz problems, although certainly in good measure economic in nature, are also in part sociological and ideological. Ultimately the problems are political, and it is the political aspects that will be weighed most heavily" (p. 4). His thesis seems to be that from Stalinist times to the present, in spite of repeated policy changes and even the ray of relief afforded in Brezhnev's revisions, there still remain two temporary ideological concessions to economic expedience. The official line is that both the kolkhoz and private garden plots and livestock will die "natural deaths" just as soon as the state sector matures to the point of providing the food "cheaper and better."

The thrust of the study can be captured in a sample of its topics: Khrushchevian Legacy; The Brezhnev-Kosygin Record; the New Kolkhoz Charter (1969); Mechanization, Specialization, and Labor Problems; The Problem of a Rational Purchase Price; the Heavy Hand of Bureaucracy; the "Link" Issue (humanizing the brigade); the Private Plot and Income of Kolkhozniks; the Problem of the Optimal Size of Farms; the Land Rent and Kolkhoz Cost-Price Problem; Postscript—the 1972 Grain Deals, the Second Fall of Matskevich, and the 1973 Harvest.

This book is not for an evening of light, entertaining reading. It is for the serious student capable of following along a literary path beset wih endless

and, at times, tedious citations and a sometimes confusing organization. It stands almost as a compilation of book reviews itself and is broader than its subtitle suggests.

The fact that the author is a professor of political science diminishes not at all the value of his scholarship for students of governmental agricultural policy in the world arena.

Robert G. F. Spitze
University of Illinois

Smith, V. Kerry. *Technical Changes, Relative Prices, and Environmental Resource Evaluation*. Baltimore: Johns Hopkins University Press for Resources for the Future, 1974, x + 106 pp., $8.00.

This monograph seeks to provide an analytical framework for linking relative price behavior, specifically increasing relative value of amenity services from natural environments, to the forces of technical change and intertemporal externalities. The framework to establish that link is outlined in a relatively systematic and concise manner contained in five short chapters (chapters 2–6) with short statements at the end of each summarizing the developments and conclusions of each stage. Both demand and supply forces which influence the relative value of amenity services and hence the allocation of environmental resources are characterized by the use of simple general equilibrium models. The monograph contains an interesting and perceptive introduction relating decisions concerning the preservation versus development of natural environments and information needed in the benefit-cost convention used to make such decisions. Chapter 2 reviews the modeling of technical change while chapters 3–6 develop the general equilibrium models used and introduce the effects of technical change and irreversibility (a specific intertemporal externality) on the supply and relative prices of fabricated goods and amenity services. The final chapter summarizes the major conclusions.

The subject covered and information obtained from the modeling effort is relevant and timely. Three legislative actions of the past decade, the Wilderness Act of 1964, the Wild and Scenic Rivers Act of 1968, and the National Environmental Policy Act of 1969, intended to protect specimens of the natural environment have brought considerable burden to analysis and evaluation of land use allocation decisions by various land management agencies. A special methodological problem arises when evaluating the benefits derived from different uses to which particular land sites may be put. The convention in benefit-cost analysis of assuming that price levels remain constant may be in error if systematic changes in relative benefits induced by differential incidence of technical change are the case. The significance of such changes in benefits has only recently been perceived in the benefit-cost evaluation of wild and scenic rivers and land sites. The author investigates those supply and demand conditions that would need to be obtained in order for goods and services, particularly amenity services of natural environments, to experience relative price appreciation due to differential incidence of technical change and intertemporal externalities.

While the general equilibrium models developed are simple and include simplifying assumptions, many of which are rather restrictive, the approach does bring us closer to being able to incorporate and trace relative price changes in the conventional cost-benefit framework. Moreover, the link between systematic changes in relative benefits, technical change, and intertemporal externalities is developed using simple neoclassical production and utility theory which should be well within the grasp of the economic analyst. Consequently, the implications of the comparative static results of the models developed can readily be explained to land use policymakers as well as stimulate application of the models to an array of preservation versus development issues. This is in contrast to much of the literature on growth and environmental quality which currently remains in the abstract.

The conclusions of the analysis that amenity services are income-elastic and few, if any, good substitutes for these services exist, and that technical change favors the supply of fabricated goods relative to amenity services, hence appreciation of the value of amenity services, are important. It is the influence of these forces that should be incorporated in the adjustments of the benefit-cost evaluation convention. Traditionally, economists and others have attempted to adjust benefit-cost estimates for inflationary or deflationary price movements, but without much success in linking these adjustments to such non-project-related forces as the effects of technical change and intertemporal externalities.

That the irreversibility effect, i.e., the presence of intertemporal externalities, decreases intertemporally the supply of amenity services and hence accentuates the appreciation of their value appears to be an oversimplified conclusion derived only from characteristics of supply. It would seem that the irreversibility effect also influences the value of amenity services through forces of demand that may be complicated by the existence of option demand. Risk and uncertainty enter to complicate the community's choice between the preservation and the development options. It would appear that the link between risk and the magnitude of the "option price" is neither direct nor one-sided, but that the prospect of transforming uncertainty to risk statements combined with the irreversibility of the development alternative induces a positive option value in favor of preservation, that is, the option value is generated by the prospect of more complete information concerning the two alternatives.

While the author's study does not present a much needed general economic theory of land use, it renders a service in extending the life of the cost-benefit convention in evaluating preservation versus development issues. The study stops short of applying the models developed to an array of cases involving decisions to develop or preserve natural environments, but does point the way to empirical study. Of course, such nasty empirical problems as measuring amenity service output, taking account of the unpriced consumption of common property resources, and more careful evaluation of technical change still exist. The book is intended to be read and understood by the economic theoretician, but the general conclusions, in simpler form, should find their way into the evaluative techniques incorporated by land management agencies and should influence more accurate evaluation of land use policy. Economists seriously intending to comprehend land use, common property, and natural resource allocation issues will find this short theoretical development useful indeed.

Terry Glover
Utah State University

Books Received

Ahmed, Mansoor. *The Economics of Nonformal Education Resources, Costs and Benefits.* New York: Praeger Publishers, 1975, xi + 122 pp., $12.50.

Aranha, Shri Felix. *The Small Farmers (1967–69).* Bombay: Ahura Printing Press, 1974, xvi + 247 pp., $17.00.

Aylward, Francis, and **Mogens Jul.** *Protein and Nutrition Policy in Low-Income Countries.* New York: Halsted Press, 1975, xiv + 150 pp., $6.95.

Blitzer, Charles R., Peter B. Clark, and **Lance Taylor.** *Economy-Wide Models and Development Planning.* New York: Oxford Press, 1975, xiii + 369 pp., $23.75.

Burrows, John. *Kenya: Into the Second Decade.* Baltimore: Johns Hopkins University Press, 1975, xiii + 533 pp., $18.50, $6.95 paper.

Crafts, Alden S. *Modern Weed Control.* Los Angeles: University of California Press, 1975, 440 pp., $15.75.

Evenson, Robert E., and **Yoav Kislev.** *Agricultural Research and Productivity.* New Haven: Yale University Press, 1975, xi + 205 pp., $12.50, $3.95 paper.

Gollnick, Heinz G. L. *Dynamic Structure of Household Expenditures in the Federal Republic of Germany.* The Netherlands: North-Holland Publishing Co., 1975, xii + 251 pp., $29.25.

Hayami, Yujiro. *A Century of Agricultural Growth in Japan.* Minneapolis: University of Minnesota Press, 1975, xvii + 248 pp., $17.50.

Hill, Dennis S. *Agricultural Insect Pests of the Tropics and Their Control.* New York: Cambridge University Press, 1975, 516 pp., $34.50.

James, Sydney C. *Midwest Farm Planning Manual.* Ames: Iowa State University Press, 1975, 333 pp., $8.50.

Johnson, Sherman E. *From the St. Croix to the Potomac: Reflections of a Bureaucrat.* Montana: Big Sky Books, 1974, 289 pp., price unknown.

Kellogg, Charles E. *Agricultural Development: Soil, Food, People, Work.* Madison: Soil Science Society of America, 1975, xii + 233 pp., $8.75.

Lele, Uma. *The Design of Rural Development.* Baltimore: Johns Hopkins University Press, 1975, xiii + 246 pp., $12.00, $3.95 paper.

Lim Lin Shu, David. *Supply Responses of Primary Producers.* Kuala Lumpur: University of Malaya Press, 1975, xvii + 166 pp., price unknown.

Mandell, Lewis. *The Demand for Money in Israel.* New York: Marcel Dekker, 1975, ix + 118 pp., $12.50.

Merva, George E. *Physioengineering Principles.* Westport, Conn.: AVI Publishing Co., 1975, ix + 353 pp., $32.00, $15.00 paper.

Mitchell, William E., John H. Hand, and **Ingo Walter.** *Readings in Macroeconomics; Current Policy Issues.* New York: McGraw-Hill Book Co., 1974, x + 514 pp., $6.95.

Mosher, A. T. *Serving Agriculture as an Administrator.* New York: Agricultural Development Council, 1975, xiii + 64 pp., price unknown.

Mount, James L. *The Food and Health of Western Man.* New York: Halsted Press, 1975, xi + 270 pp., $14.95.

Ott, David J., Attiat F. Ott, and **Jang H. Yoo.** *Macroeconomic Theory.* New York: McGraw-Hill Book Co., 1975, x + 401 pp., price unknown.

Papers and Reports, Fifteenth International Conference of Agricultural Economists: The Future of Agriculture Technology, Policies and Adjustment. Oxford: Oxford Agricultural Economics Institute for International Association of Agricultural Economists, 1973, xx + 537 pp., price unknown.

Reynolds, Lloyd G. *Agriculture in Development Theory.* New Haven: Yale University Press, 1975, x + 510 pp., $25.00.

Robinson, Glen O. *The Forest Service.* Baltimore: Johns Hopkins University Press, 1975, xv + 337 pp., $16.95, $4.95 paper.

Shideler, James H. *Agriculture in the Development of the Far West.* Washington: The Agricultural History Society, 1975, ix + 316 pp., price unknown.

Singer, H. W. *The Strategy of International Development: Essays in the Economics of Backwardness.* New York: International Arts & Sciences Press, 1975, xvi + 248 pp., $20.00.

Smith, Frederick J. *The Fisherman's Business Guide.* Camden: International Marine Publishing Co., 1975, 172 pp., $10.95.

Smith, Wallace F. *Urban Development: The Process and the Problems.* New York: University of California Press, 1975, xvii + 381 pp., $14.75.

Soltow, Lee. *Men and Wealth in the United States 1850–1870.* New Haven: Yale University Press, 1975, xx + 206 pp., $12.50.

Sysoev, N. P. *Economics of the Soviet Fishing Industry.* Russian: Israel Program for Scientific Translations, 1974, xiv + 386 pp., price unknown.

West, H. W., and **O. H. M. Sawyer.** *Land Administration: A Bibliography for Developing Countries.* Cambridge: University of Cambridge, 1975, x + 292 pp., $2.50.

Ziegler, Louis W., and **Herbert S. Wolfe.** *Citrus Growing in Florida.* Gainesville, Florida: University of Florida Press, 1975, x + 246 pp., $10.00.

News

Announcements

Annual Meeting, 1976

The annual meeting of the American Agricultural Economics Association will be held August 15–18 at Pennsylvania State University in University Park, Pennsylvania. Professor James Holt is chairman of the local arrangements committee, and correspondence concerning the meeting should be directed to him. The Northeastern Agricultural Economics Council will be meeting jointly with the AAEA. A letter concerning the details of the program has been sent to all AAEA members. Further program information will be included in mailings from the local arrangements committee.

Contributed Papers for the Annual Meeting

Authors who would like manuscripts considered for the contributed papers sessions should submit the proposed titles to the chairman of the contributed papers session before May 1. Final manuscripts must be in the hands of the chairman by May 15. (This date is advanced from previous years because many members will be attending the International Association of Agricultural Economics meetings prior to the AAEA meetings.)

Contributed papers related to extension, teaching, research, or business phases of the economics of agriculture, natural resources, and rural and community development will be considered. Each author is limited to one contributed paper in which he or she is the sole or senior author. Contributions from undergraduate students are welcome.

Manuscripts should follow *Journal* manuscript guidelines (see the inside back cover of this issue). Since only twenty to twenty-five minutes will be available for the introduction, presentation, and discussion of each paper, the manuscript should not exceed twelve double-spaced pages.

Each manuscript must be accompanied by two copies of a double-spaced, fifty-word abstract. Abstracts of papers presented in the contributed papers sessions will be printed in the proceedings issue of the *Journal*, and authors should consult the December 1975 issue for the format of the abstract. Copies of the abstracts will also be available at registration and in advance of the session.

Authors of contributed papers are invited to submit their manuscripts to the editor of the *Journal* to be considered for publication. Such papers are subject to the normal review process.

The chairman of the contributed papers session is Dr. Quentin M. West, Administrator, Economic Research Service, U.S. Dept. of Agriculture, Washington, D.C. 20250.

Page Charge Policy

The AAEA Directors have voted to limit the exemptions from the page charge. Papers invited for presentation at the annual meetings and subsequent publication in the *Journal* will generally be subject to the charge. Authors should assume that the charge is applicable unless they receive explicit written exemption from the AAEA President. The revised policy statement appears inside the back cover of this issue.

NACTA Meets in Lubbock

The National Association of Colleges and Teachers of Agriculture will hold its annual meeting June 16–18, 1976, on the campus of Texas Tech University in Lubbock, Texas. The annual meeting will feature presentations on effectiveness in teaching, trends in agricultural curricula, and items of interest to teachers of agriculture. For information on the meetings, write Dr. J. Wayland Bennett, Box 4190, Texas Tech University, Lubbock, TX, 79409.

UMR-MEC Energy Conference

The University of Missouri-Rolla in cooperation with the Missouri Energy Council is sponsoring the third annual UMR-MEC Energy Conference, to be held October 12–14, 1976. The theme of this year's conference is "Energy Crises: An Evaluation of Our Resource Potential." Papers, which may be of an applied, theoretical, or interdisciplinary nature, should be submitted for review by June 1, 1976. We encourage economists from government and industry, as well as academic economists, to participate. The program chairpersons for economics are Christopher Garbacz, Vaman Rao, and William Desvousges, Economics, University of Missouri-Rolla, Rolla, Missouri, 65401.

Symposium on Animal Feeding

A symposium on "Feed Composition, Animal Nutrient Requirements, and Computerization of Diets" will be held at Utah State University, Logan, Utah, July 11–16, 1976. Internationally known scientists, representatives from industry, and government agencies from the United States and various countries in the world will participate.

Sponsored by the Committee on Animal Nutrition, National Research Council of the National Academy of Science (CAN NRC-NAS); the U.S.

Agency for International Development (AID); the International Network of Feed Information Centers (INFIC), Utah State University; and hosted by Dr. Lorin E. Harris, Professor of Animal Science and Director, International Feedstuffs Institute, Utah State University, meetings will be conducted in English, and interpreters will be available for French, German, Portuguese, and Spanish.

During the week of the symposium, five main topics will be covered. Monday, there will be meetings and discussions on feed composition; Tuesday, the subject will be nutrient utilization; Wednesday, calculating requirements of animals; Thursday, formulating diets for maximum profit; and Friday, practical system for diet formulating and animal management.

The symposium is concentrating on the use of feed composition data and nutrient requirement information in computer calculation of animal diets. Mathematical models that describe the utilization of nutrients by animals will be emphasized. The aim is to use information that describes nutrient utilization and animal requirements to produce the most profitable diet formula for animals in various physiological states and environments. Methods for solving livestock feeding and management problems will be presented.

Contact Dr. Lorin E. Harris, International Feedstuff Institute, Department of Animal Science, UMC 46, Utah State University, Logan, Utah 84322, or phone (801) 752-4100, Ext. 7424 for further information.

New Department

Under the reorganization of the College of Agriculture at Prairie View A&M University, Prairie View, Texas, a new Department of Agricultural Economics and Rural Sociology has been created. Vance W. Edmondson has been appointed head of the new department while retaining his joint agricultural economics research appointment with the Texas Agricultural Experiment Station and Prairie View A&M University, the 1890 land grant college of Texas.

Name Change

The name of the Department of Agricultural Economics at the University of Connecticut, (Storrs) has been changed to the Department of Agricultural Economics and Rural Sociology, effective July 1, 1975.

Personnel

University of Arizona

Correction: Jimmye Hillman remains as head of the Department of Agricultural Economics and is also a member of the Hazardous Materials Advisory Committee of the Environmental Protection Agency.

University of Arkansas

Appointments: James I. Martin, formerly of Virginia Polytechnic Institute and State University, is a vice president of the university; **Ralph D. May,** Ph. D. Purdue University, is an assistant professor.
Honor: H. J. Meenen, head of the Department of Agriculture and Rural Sociology, was elected president of the Southern Agricultural Economics Association for 1975–76.

University of California, Davis

Appointments: Philip L. Martin, Ph. D. University of Wisconsin, **Refugio I. Rochin,** formerly with the Ford Foundation in Bogota, Colombia, and **Barbara Zoloth,** Ph. D. University of Minnesota, are assistant professors.
Leaves: Sylvia Lane, professor, is at the Food Research Institute, Stanford University during 1975–76; **Alex F. McCalla,** professor, is on sabbatical leave but stationed at the university during 1975–76.

Canada Agriculture

Appointment: Robert W. Jolly, at work on a Ph. D. at the University of Minnesota, is with the Research Station, Bureau of Agricultural Economics, Lacombe, Alberta.

University of Chicago

Return: G. S. Tolley is back after serving as Deputy Assistant Secretary of the Treasury for Tax Policy during 1974–75.

CED: Commodity Economics Division of the Economic Research Service, USDA; **EDD:** Economic Development Division of ERS; **FDCD:** Foreign Demand and Competition Division of ERS; **NEAD:** National Economic Analysis Division of ERS; **NRED:** Natural Resource Economic Division of ERS.

Clemson University

Appointments: Larry L. Bauer, former associate professor, University of Tennessee, and **Harold M. Harris,** former assistant professor, Virginia Polytechnic Institute and State University, are associate professors; **Clayton Grant,** former associate professor, Jacksonville State University, is a visiting assistant professor.

Colorado State University

Appointment: Sam H. Johnson III is on a two-year assignment with the Water Management Research Project Field Party and U.S. Agency for International Development in Pakistan.
Return: Albert G. Madsen is back after a two-year assignment with AID.

University of Connecticut

Appointment: George A. Ecker, professor, is acting head of the Department of Agricultural Economics and Rural Sociology.

Cornell University

Appointment: T. T. Williams, professor, Southern University, is an adjunct professor.

University of Florida

Appointments: W. Arden Collette, Danny L. Gunter, and **John A. Otte** are new faculty members; **W. Kary Mathis** is director of the Agricultural Marketing Research Center.
Leave: Max R. Langham is research coordinator, Asia, for the Agricultural Development Council during 1976.

University of Georgia

Leave: Joseph C. Purcell is with the Cooperative States Research Service.

University of Hawaii

Appointments: Wen-yuan Huang, Ph.D. University of Hawaii, is an assistant professor; **J. Louis Williams,** formerly with the University of Georgia, is

an associate professor and associate extension specialist.

University of Idaho

Appointment: James R. Jones, Ph.D. University of Arkansas, is an assistant professor.

Iowa State University

Appointments: John Achterhof and **Lizardo de las Casas** are research associates in economics; **John Strauss** is a temporary assistant professor of economics.
Resignation: Richard A. Levins, former research associate in economics.

Kansas State University

Appointment: T. Roy Bogle, former area extension economist, is an extension economist in farm management.

Louisiana State University

Appointment: Sanford B. Dooley, Ph.D. Purdue University, is an assistant specialist in the Cooperative Extension Service.

University of Manitoba

Leave: Edward W. Tyrchniewicz, professor of agricultural economics, is the research coordinator for the Commission of Inquiry into Grain Handling and Transportation.

University of Maryland

Appointment: John M. Curtis, former chairman of the Department of Agriculture and Resource Economics, is the director of the state-wide Cooperative Extension Service.

University of Minnesota

Appointment: Abraham Subotnik, a faculty member at Technion, Israel Institute of Technology, Haifa, Israel, is a visiting associate professor during 1975–76.
Leave: Lee R. Martin, professor, is with AID doing research on agricultural development problems and factor analysis during 1975–76.
Resignations: Harold E. Klein, former associate professor and a member of the Minnesota team in Tunisia, is with the School of Business Administration, Temple University; **Robert M. Reeser,** former professor and a member of the Minnesota team in Tunisia, is with the Lang Engineering Corporation, Coral Gables, Florida.

Mississippi State University

Appointments: James Richard Conner, former director of Planning and Analysis for the State University System of Florida, is an associate professor and associate economist in regional economics; **Lennie G. Kizer,** former assistant professor at Pennsylvania State University, is associate professor and associate economist in agricultural financial management.

University of Missouri

Appointment: John B. Doll, chairman of the Economics Department, is the associate dean of the College of Arts and Sciences.

Montana State University

Leave: Malcolm D. Bale, assistant professor, is a visiting economist with FDCD.

University of Nebraska

Resignation: P. W. Lytle, former associate professor, is with The Andersons, Maumee, Ohio.

North Dakota State University

Appointments: F. Larry Leistritz is the associate director for social sciences to the Regional Environmental Assessment Program, Bismarck, North Dakota, on a half-time basis; **George H. Pfeiffer,** Washington State University, **Arlyn Staroba,** M.S. North Dakota State University, and **Norman Toman,** M.S. North Dakota State University, are research associates.
Leave: Robert G. Johnson is on a nine-month Fulbright Hays Fellowship at the Agricultural Institute of Economics and Rural Welfare Center, Dublin, Ireland.

Oregon State University

Appointments: John L. Ball, Jr., M.S. University of Hawaii, is a visiting assistant professor and extension marine economist during 1975–76; **Stanley F. Miller,** associate professor and director of the International Plant Production Center, is the director of a new AID grant for the development of dryland agriculture in less developed countries.

Resignation: Emery N. Castle, former dean of the Graduate School, is Senior Fellow and Vice President of Resources for the Future.

Pennsylvania State University

Appointments: Jerry A. Fedeler, formerly with Iowa State University, is an assistant professor; **Leonard Kyle,** formerly with Michigan State University, is a professor and resident economist on the Bahamas Agricultural Research, Training, and Development Project, Andros Island, Bahamas.
Leave: J. Patrick Madden, professor, is at ABT Associates, Cambridge, Massachusetts during 1975–76.

Prairie View A&M University

Appointment: Vance W. Edmondson, former associate professor at Texas A&M University, is head of the Department of Agricultural Economics and Rural Sociology.

Purdue University

Appointments: Bruce L. Brooks is a visiting professor of marketing and business management; **George F. Patrick** is an assistant professor of production economics and farm management.
Resignations: Ralph M. Brooks; Arlo J. Minden.
Leave: Joseph N. Uhl is a visiting professor at the University of California, Davis.
Honors: J. Carroll Bottum was made a Kentucky Colonel by the Society of Agricultural Farm Managers and Rural Appraisers in Lexington, Kentucky; **Wilmer A. Dahl** received the American Institute of Cooperation's 1974–75 Nourse Award for the best Ph.D. thesis on a subject related to U.S. agricultural cooperatives; **George Lee** and **Kurt Klein** received a certificate of merit for the best journal article of 1974 by the Canadian Agricultural Economics Society; **Eric C. Oesterle** received the 3rd Annual Grocers Spotlight Award; **Sam Parsons** and **David C. Petritz** won the 1975 Extension Educational Aids Blue Ribbon Award.

Rutgers University

Appointments: A. Robert Koch, head of the Department of Agricultural Economics and Marketing; **Dennis J. Palmini,** former research associate, University of Illinois, is an assistant professor.

Texas A&M University

Appointments: Dean M. Ethridge, formerly with the University of Georgia, is an assistant professor at the Marketing Research Center; **Dan Hardin,** former research assistant, Oklahoma State University, is a research associate in programming; **Charles Hodges,** former agricultural representative with a private lending institution, is a research associate at the Marketing Research Center; **Judith Houston,** former instructor of economics, Utah State University, is an assistant professor; **Ronald D. Knutson,** former administrator of the Farmer Cooperative Service, USDA, is a professor in extension, teaching, and research; **Larry C. Morgan,** former assistant professor, University of Tennessee, is an assistant professor of rural sociology and agricultural economics; **John B. Penson,** former ERS agricultural economist, Purdue University, is an assistant professor in agricultural finance.
Resignation: J. Michael Sprott, former associate professor, is the director of the Alabama Extension Service.

U.S. Department of Agriculture

Appointment: Walter L. Fishel, former associate professor, University of Minnesota, is on the program analysis and coordination staff, Agricultural Research Service.
Retirement: Harry C. Trelogan, former administrator of the Statistical Reporting Service.
Appointments in CED: Joseph Arta is with the Meat Animals Program Area; **Maury E. Bredhal,** is on the Forecast Support Staff and is an assistant professor, University of Minnesota; **O. A. Cleveland** is in Stoneville, Mississippi; **Dave Colver** is on a two-year duty tour in Korea; **Pete Emerson** is with the Office of Planning and Evaluation; **Don E. Etheridge** and **R. Samuel Evans** are with the Fibers Program Area; **Paul W. Gallagher** and **Charles Overton** are with the Forecast Support Staff; **Virden Harrison** is with the Clay Center, Nebraska; **Walter Heid** is at Kansas State University; **J. B. Penn** is in Washington, D.C.; **Dale Shaw** is in Lubbock, Texas; **Donald Van Dyne** is with the Poultry Program Area; **Mellie Warner** is with the Grains Program Area; **Glen Zepp** is with the University of Florida.
Retirement in CED: J. C. Eiland, formerly with the Grains Program Area.
Appointments in EDD: Lloyd D. Bender is the project leader, Energy Development Impact Project; **Jeff V. Conopask,** Ph.D. Virginia Polytechnic Institute and State University, is with the Analysis Program Area; **Fred K. Hines** is program area leader, Area Analysis Program Area; **Ronald W. Holling** is with the Manpower Studies Group; **Thomas A. Sachs** and **William Sinclair** are with the State and Local Government Program Area.
Appointments in NEAD: Burl Back is head of a special project, Food and Fiber Program Area; **Arvin R. Bunker** is with the Transportation Economic Program Area; **Susan Cobb** is with the Consumer Interest Program Area; **Floyd D. Gaibler** is with the Transportation Economics Program

Area; **George St. George** is with the Demand Analysis Program Area; **James Schwinden** is with the Transportation Economics Program Area.
Retirement in NEAD: William H. Scofield.

Virginia Polytechnic Institute and State University

Appointment: James D. Dean, B.S. Ohio State University, is a research associate.

Washington State University

Appointment: Gayle S. Willett, formerly with the University of Arizona.

University of Wisconsin

Honor: Douglas Yanggen received the Soil Conservation Society of America's Commendation Award in recognition for his work on the legal and economic aspects of land use.

University of Wyoming

Appointment: James J. Jacobs, Ph.D. Iowa State University, formerly with NRED, Cornell University, is an associate professor.

Other Appointments

Salem Gafsi, Ph.D. University of Minnesota, is with the International Bank for Reconstruction and Development.
Joseph Howard Gill, M.S. Purdue University, is an extension agent, Cooperative Extension Service, Lafayette, Indiana.
Kenneth L. Graber, M.S. Purdue University, is an agricultural missionary, Board of Global Ministries, United Methodist Church, Cochabamba, Bolivia.
Ioannis Karmokolias, Ph.D. Virginia Polytechnic Institute and State University, is with James R. Leonard Associates, Washington, D.C.
George Lee, formerly with Purdue University, is an associate professor, University of Saskatchewan.
Clarence J. Miller is the UN E.C.A. regional advisor in Addis Ababa, Ethiopia.
Sang-Woo Park, Ph.D. University of Minnesota, is with the Ministry of Agriculture and Fisheries Division of General Affairs, Seoul, Korea.
William B. Riley, Jr., Ph.D. University of Arkansas, is an assistant professor of business administration, St. Cloud State University.
Donnie A. Smith, M.S. University of Arkansas, is a county extension agent, Cooperative Extension Service, Jonesboro, Arkansas.
John Shipley Young, M.S. Purdue University, is vice president of Melrose Farms, Herndon, Kentucky.

Obituaries

John Lossing Buck

John Lossing Buck, the builder of the Department of Agricultural Economics at the University of Nanking, China and its head for two decades, died September 27, 1975, two months prior to his 85th birthday.

Buck went to China in 1915 as an agricultural missionary in Anhwei Province, 200 miles north of Nanking. Five years later, the University of Nanking invited him to join its faculty and to initiate work in agricultural economics. It was here that he introduced the discipline to China in all its aspects: teaching, research, and public service. Perhaps his greatest accomplishment was inspiring and training young Chinese in this new field of study. In less than two decades, these young men under Buck's leadership built one of the largest and strongest departments in the College of Agriculture and the only significant program in agricultural economics in China. The Sino-Japanese War interrupted academic life and forced the university to move first to Hankow and later to Chengtu in western China.

Dr. Buck trained his students in methods of obtaining economic information where little or none existed. They learned how to collect data systematically in the field, analyze them, and organize the results for publication. His group undertook short-run crises projects occasioned by floods and famine and was recognized by public officials as a dependable source of useful information. The group also undertook more traditional studies of farm management, cooperatives, marketing, land use, and prices. Buck was a pioneer at institution building in an underdeveloped country.

After the war, Buck left China but returned for several months in 1946 as a member of the China-United States agricultural mission under the auspices of the U.S. Department of Agriculture. Later he served as chief of the Land and Water Use Branch of the Food and Agriculture Organization of the United Nations. In 1954, he returned to the United States and was director of agricultural economics for the Council of Economic and Cultural Affairs (now the Agricultural Development Council) until he retired in 1957.

In his first book, *Chinese Farm Economy*, published in 1930, he reported on a study of 2,866 farms in seventeen localities in China. He later authored *Land Utilization in China*, a three-volume report of a massive survey of the whole of rural China published by the University of Chicago Press in 1938. In 1973, he wrote *Development of Agricultural Economics at the University of Nanking, Nanking, China, 1926–1946*, which was published as Cornell International Agricultural Development Bulletin No. 25.

Buck was born at Pleasant Valley, New York on November 27, 1890. He received the B.S. degree in 1914, M.S. in 1925, and Ph.D. in 1933, all from Cornell University. Buck's first marriage to the late Pearl S. Buck ended in divorce in 1935. He later married Lomay Chang who survives him, as does a son, Paul, and a daughter, Rosalind Lewis. He is also survived by two daughters of his first marriage, Carol and Janice.

George L. Capel

George L. Capel, assistant director of the North Carolina Agricultural Extension Service, died in Raleigh, North Carolina, October 7, 1975.

Capel was born in Garysburg, North Carolina in 1923. He attended North Carolina State College prior to World War II. He served as a naval officer during the war. He returned to North Carolina State University and received a B.S. degree in agricultural economics in 1948 and an M.S. in 1949. Capel was then employed by the Farmer Cooperative Service in Washington, D.C. He transferred to Gainesville, Florida and the BAE in 1952, where he worked on fruit and vegetable marketing problems. He received a Ph.D. from the University of Florida in 1956. In 1961, he returned to North Carolina State University as specialist in Charge of Extension Marketing Programs. In 1968, he was promoted to assistant director of the Agricultural Extension Service.

In addition to his work, George Capel devoted his considerable talent and skills to his community, his church, and above all his family. He served the American Agricultural Economics Association as a member of the Publications Awards Committee from 1972–75.

To those who knew him, it was the sheer joy of being in his presence, anywhere or any time, that will be remembered. He was a man of uncommon wit and humor. He was also a gentle person. The combination made George Capel an absolutely delightful colleague, friend, or supervisor. Those who knew him will not soon forget him.

He is survived by his widow Marie, son James, and daughter Gail.

Dennis E. Crawford

Dennis E. Crawford, 61, associate professor at Clemson University, died unexpectedly at his home August 5, 1975.

Crawford was a native of Clemson, South Carolina, and received both his B.S. and M.S. de-

grees in agricultural economics from Clemson. He came to work with the Department of Agricultural Economics and Rural Sociology in 1936 and has been employed by the department continuously since that time, except for a seven-month period in 1943 when he was employed by the Soil Conservation Service, U.S. Department of Agriculture.

During his career, Crawford's research interests included numerous areas in farm management and agricultural marketing. Over the last several years, he had studied trends in the use of cotton and competing fibers, the costs of cotton ginning, the availability and use of agricultural credit, the economics of caged-layer egg production, and the economics of hay harvesting and handling systems. Most recently, he was engaged in development of farm enterprise budgets by computer for use in extension farm management programs. Perhaps his greatest contributions to the programs of the university, however, arose from his detailed knowledge of where needed publications and information were located, and in his matchless skill in obtaining cooperation among diverse individuals and groups. He made his knowledge and services available for the asking to associates and students in the department, college and university, and to many others.

He is survived by his wife, Anne, a daughter and a son, as well as a brother and a sister.

Perry Virgil Hemphill

Perry Virgil Hemphill died on March 8, 1975 near Tucson, Arizona at the age of 79. He is survived by his wife, Martha, a son, Harlan, and several grandchildren.

Hemphill was born in Partridge, Kansas on June 12, 1896. He received his B.S. and M.S. degrees from Colorado State University in agricultural economics. After completion of his M.S. degree, he taught high school and then worked as an agricultural economist for several federal agencies. Perry came to North Dakota Agricultural College as an Extension Grain Marketing Specialist in 1937. He began his teaching career in 1942, when he became an assistant professor of agricultural economics. He moved up the ranks and held the rank of professor of agricultural economics at North Dakota State University when he retired in 1967. During the 1954–55 year, he was acting chairman of the department.

Perry V. Hemphill is best remembered by people who were associated with him as a dedicated teacher and researcher. Those who worked with him or had him as an adviser or instructor remember him best as one who gave untiringly of his time and talents to all who came to him. He was always willing to listen to a student's problems and counsel him in his career decisions. His wisdom, kindness, and good judgment touched the lives of thousands of people during his long career.

All who had the privilege of knowing Perry V. Hemphill were deeply saddened by his untimely death in an automobile accident, which also took the lives of his son, Eldon, and Eldon's wife near Tucson on March 8, 1975. Perry's wife, Martha, survived the accident and resides in Elkhorn, Iowa.

THE AUSTRALIAN JOURNAL OF AGRICULTURAL ECONOMICS

PUBLISHED BY THE AUSTRALIAN AGRICULTURAL ECONOMICS SOCIETY

Vol. 19 | December 1975 | No. 3

STUART HARRIS *Tariff Compensation: Sufficient Justification for Assistance to Australian Agriculture?*

P. J. LLOYD *Tariff Compensation: An Undesirable Policy*

J. W. FREEBAIRN *Forecasting for Australian Agriculture*

PATRICK MINFORD *Textile Fibre Substitution and Relative Prices*

GRAEME OLSEN *Option Value*

JOHN W. LONGWORTH *and* DON RUDD *Plant Pesticide Economics with Special Reference to Cotton Insecticides*

Book Reviews

Editors: Dr. A. S. Watson and Dr. I. R. Wills, C/- School of Agriculture and Forestry, University of Melbourne, Parkville, Victoria, 3052.

Membership: $12 (Australian) from the Secretary, Mr. H. J. Plunkett, Bureau of Agricultural Economics, P.O. Box 1563, Canberra City, A.C.T., 2601, Australia.

CANADIAN JOURNAL OF AGRICULTURAL ECONOMICS

Vol. 23, No. 3 | November/novembre, 1975

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Temporal Price Relationships in the Vancouver Rapeseed Futures Market and Their Implications to Farm Prices .... *Larry Martin and Gary G. Storey*

An Integrated Econometric Model of The Canadian Livestock Feed Sector .... *Surendra N. Kulshreshtha and Eddy W. Reimer*

Food Cost Stabilization Using Food Coupons .... *Wilfred Candler and George Kennedy*

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Towards Practical Guidelines for Multiple Use Management ...... *O. T. Kingma and J. A. Sinden*

Comment

Resource Allocation Methods in Agricultural Research: Some Comments on Russell's RASAR .... *M. S. Makower*

Book Review

Published by The Canadian Agricultural Economics Society
Editors: W. E. Phillips and M. M. Veeman
Department of Agricultural Economics and Rural Sociology,
University of Alberta, Edmonton, Alberta, Canada T6G 2H1

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—publishing the *American Bibliography of Agricultural Economics* and supporting an associated retrospective literature search in cooperation with the U.S. Department of Agriculture;
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American Journal of Agricultural Economics

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May 1976

In this issue: Proceedings papers from the 1975 winter meeting

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Communications concerning books for review and books submitted for announcement in the *Journal* should be sent to the book review editor, Francis E. Walker, Department of Agricultural Economics and Rural Sociology, Ohio State University, Columbus, Ohio 43210.

American Journal of Agricultural Economics

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News

The Impact of Increasing Food Supply on Human Nutrition: Implications for Commodity Priorities in Agricultural Research and Policy

Per Pinstrup-Andersen, Norha Ruiz de Londoño, and Edward Hoover

A procedure is developed to estimate the nutritional implications of alternative commodity priorities in agricultural research and policy. The model estimates the distribution of supply increases among consumer groups, the related adjustments in total food consumption, and implications for calorie and protein nutrition. Findings from an empirical application of the model to the population of Cali, Colombia, suggest that relative increase in total nutrient supply is a poor indicator of relative nutritional impact because both nutritional waste and consumer adjustment in total food consumption are a function of the commodity from which the additional nutrients are obtained.

Key words: agricultural research priorities, human nutrition, income distribution, price elasticities, research resource allocation.

Malnutrition, primarily calorie and protein deficiencies, has been widely recognized for some time as a serious problem among low income groups of the population of many developing countries. However, only recently has improved human nutrition become an important part of development goals in most of these countries. As more emphasis is placed on equity and welfare in overall development plans, improved nutrition is gradually being accepted by government planners and politicians as a worthwhile goal in itself. Furthermore, the importance of health and nutrition for human capital formation and the resulting implications for economic growth has gained wide recognition during recent years. As a result, activities with the direct aim of expanding food production, such as certain agricultural research and public policy, frequently consider improved human nutrition as one of their final goals.

Although the immediate objective of production-oriented agricultural research and public policy may be to expand food production, such an objective may be viewed as a means to reach some set of final goals, one of which possibly being improved human nutrition. The challenge to the decisionmaker in production-oriented research and policy then becomes one of choosing among alternative strategies to attempt to maximize the contribution to the final goals for any given amount of resources available. For this purpose, information is needed on expected relative contribution of alternative strategies to the achievement of specified goals and on program and associated costs of each alternative.

Little is known about the relative nutritional impact of alternative agricultural research and policy strategies. There is a tendency to consider the increase in total nutrient supply as a measure of the improvement in human nutri-

Per Pinstrup-Andersen is director of the Agro-Economic Division of the International Fertilizer Development Center, Florence, Alabama; Norha Ruiz de Londoño is a research assistant at Centro Internacional de Agricultura Tropical, Cali, Colombia; and Edward Hoover is a graduate student in the Department of Systems and Industrial Engineering at the University of Arizona.

The authors are grateful to James Cock, Alain de Janvry, David Franklin, and Grant Scobie for valuable comments on an earlier draft of this article.

tion. But increases in nutrient supply will make a positive contribution to human nutrition only if the consumer is deficient in the particular nutrient in the absence of the supply increase. Nutrient supply increases of equal magnitude but originating from different commodities may have different impacts on human nutrition because the distribution of the additional supply among consumer groups differs. Hence, to establish commodity priorities in research and policy aimed at expanding food production for the purpose of improving human nutrition in the most effective way, it is essential to estimate not only expected increases in nutrient supply but also what proportion of the supply increase will be consumed by deficient consumer groups and the resulting adjustments in the consumption of other foods.

Production-oriented agricultural research and policy is frequently commodity specific and priorities need to be established at two levels, choice of commodities and choice of activities within commodities. Ramalho de Castro and Schuh developed and empirically tested methodology that would assist in establishing commodity priorities in research on the basis of expected distribution of benefits between producer and consumer sectors and among factors of production within the producer sector.

The purpose of this paper is to indicate an approach to economic analysis that may help establish commodity priorities in agricultural research and public policy if improved human nutrition is a goal. Thus, the paper supplements the Ramalho and Schuh methodology by providing a means for estimating the distribution of supply increases among urban consumer groups and the resulting nutritional benefits. The issue of criteria for establishing priorities between improved urban nutrition and other goals is not treated.

A model is developed to estimate the nutritional impact of expanding the supply of any one of the foods currently available to the consumer.[1] On the basis of this model, an empirical analysis is carried out with sample data from Cali, Colombia. This paper presents the model, briefly describes the data requirements and sample characteristics, summarizes the empirical findings, and discusses the utility and limitations of the model for establishing nutrition-oriented priorities in agricultural research and public policy.

[1] Only the nutritional impact due to change in calorie and protein intakes is considered in the model. Possible impact due to changes in other nutrients and interactions among nutrients is ignored.

The Model

The model is based on neoclassical demand theory. It is presented in two parts, the first referring to the estimation of a price elasticity of demand matrix for each of a number of income strata and for the market as a whole and the second dealing with the distribution of a hypothetical supply increase of any one good among these income strata, the resulting adjustments in consumption of all other goods, and the impact on calorie and protein nutrition.

Price Elasticity Matrix

A complete price elasticity of demand matrix was estimated for each of the income strata using the methodology developed by Frisch. Assuming want independence among the commodities or groups of commodities considered, Frisch provides a method for estimating a complete set of direct and cross price elasticities of demand on the basis of income elasticities, budget proportions, and the flexibility of money.

Let $\phi = \frac{\partial w}{\partial a}\frac{a}{w}$ be the flexibility of money, where w is the marginal utility of money income and a is money income. Then, the direct and cross price elasticities of demand for income stratum m may be estimated as

$$(1)\quad e_{ii(m)} = -E_{i(m)}\left[A_{i(m)} - \frac{1 - A_{i(m)}E_{i(m)}}{\phi_{(m)}}\right],$$

and

$$(2)\quad e_{ij(m)} = -E_{i(m)}A_{j(m)}\left[1 + \frac{E_{j(m)}}{\phi_{(m)}}\right],\ i \neq j,$$

respectively, where e_{ii} is the direct price elasticity of demand for good i, e_{ij} is the cross price elasticity for good i with respect to good j, E_i and E_j are the income elasticities for goods i and j, respectively, and A_i and A_j are the budget proportions spent on goods i and j.

Assuming that all consumers are faced with the same market for any one commodity, the average per capita direct and cross price elasticities of demand for good i was estimated as the weighted average of the strata elasticities using quantity of good i consumed by stratum

m and relative proportion of total population found in stratum m as weights:

$$(3) \qquad e_{ij} = \frac{\sum_{m=1}^{n} e_{ij(m)} Q_{i(m)} N_{(m)}}{\sum_{m=1}^{n} Q_{i(m)} N_{(m)}},$$

where $e_{ij(m)}$ = direct or cross price elasticity of demand for stratum m, $Q_{i(m)}$ = quantity consumed per capita of commodity i in stratum m, and $N_{(m)}$ = population of strata m.

The assumption of want independence implies that the marginal utility of one good is independent of the quantity consumed of any other good for which want independence is assumed. Hence, if want independence is assumed for all goods, direct additivity of the utility function is implied, i.e., $u(q_1, q_2, \ldots, q_n) = u_1(q_1) + u_2(q_2) + \ldots + u_n(q_n)$ (George and King, p. 23). However, the goods are still related through the budget constraint; hence, want independence does not imply the much stronger assumption of demand independence. Although some goods, such as electricity and Swiss cheese, can safely be regarded as want independent, as argued by Frisch, the assumption is obviously not valid for all goods. It may be possible, however, to group the bundle of goods available to the consumer to obtain little or no want independence among groups (Bieri and de Janvry). Where this is possible, the Frisch scheme may then be applied to estimate group elasticities. Assuming that the consumer budget is first allocated among such groups and then the amount allocated to each of these groups is allocated to individual goods within the particular group, the two-stage maximization process may provide elasticity estimates for the individual goods (de Janvry, Bieri, and Núñez). However, in addition to the cross-section data needed to estimate income elasticities, time-series data are needed to estimate price elasticities. The applicability of the two-stage maximization process is limited because of the scarcity of reliable time-series data. Such scarcity is particularly pronounced in cases where elasticities are needed by income strata.

No reliable time-series data on prices and quantities were available for the present study. Hence, the two-stage process could not be applied. On the other hand, since the primary purpose of the study was to develop and empirically test a methodology for estimating the nutritional impact of supply expansions and not to estimate price elasticities per se, it was felt that direct application of the scheme developed by Frisch would provide sufficiently accurate elasticity estimates. This supposition was supported by the actual estimates obtained, all of which fall within expected magnitudes. However, the assumption of want independence is not likely to be valid for all goods considered; hence, the empirical results of this study should be interpreted with caution.

Change in Calorie and Protein Intakes

This part of the model quantifies the change in calorie and protein intakes by income strata caused by an externally introduced shift in the supply curve of any one of the food commodities or groups of food commodities considered. The model estimates the distribution among strata of the additional supply of the food for which the supply curve is shifted and the resulting adjustments in the consumption of all other foods and consists of a set of recursive equations. Assuming that all consumers are faced with the same market in which perfect competition exists and that prices and quantities for all foods are in equilibrium before the shift in the supply curve, the model estimates the new equilibrium for prices and quantities for all foods utilizing an iterative procedure.[2]

If the initial market equilibrium price for commodity i is P_i^o, the new equilibrium price P_i^1 after shifts in the supply and/or demand curves is estimated as (Pinstrup-Andersen and Tweeten, p. 538)

$$(4) \qquad P_i^1 = P_i^o \left[1 - \frac{\Delta S_i - \Delta D_i}{(e_{si} - e_{ii})\, Q_i^o} \right],$$

where ΔS_i = horizontal shift in supply curve of commodity i, ΔD_i = horizontal shift in demand curve of commodity i, e_{si} = price elasticity of supply for commodity i, e_{ii} = market price elasticity of demand for commodity i, and Q_i^o = initial equilibrium quantity of i.

Using a similar procedure, the new equilib-

[2] The model is static in the sense that no shifts in the demand curves can occur except those due to changes in prices of other goods brought about by the initial shift in the supply curve and subsequent adjustments, i.e., consumer incomes, tastes, preferences, and other potential demand shifters are assumed constant.

rium quantity of commodity $i(Q_i^1)$ is estimated as

$$(5) \quad Q_i^1 = Q_i^o + \Delta D_i + \frac{\Delta S_i - \Delta D_i}{1 - (e_{si}/e_{ii})}.$$

Applying these two equations, the change in price and quantity of commodity i due to an externally introduced shift in the supply curve (and no change in the demand curve) is estimated as

$$(6) \quad P_i^k = P_i^{k-1}\{1 - [B/(e_{si} - e_{ii})]\},$$

and

$$(7) \quad Q_i^k = Q_i^{k-1}\{1 + B/[1 - (e_{si}/e_{ii})]\},$$

where $k = 1$, and $B = \frac{\Delta S_i}{Q_i^{k-1}}$ = the horizontal shift in supply curve as a proportion of initial quantity.

The final equilibrium price and quantity would be P_i^1 and Q_i^1 for good i if, respectively, $e_{ji} = 0$ or $e_{ij} = 0$ for all $j \neq i$ where e_{ij} is the cross price elasticity of demand for commodity i given a change in the price of j. Furthermore, if $e_{ji} = 0$ for all $j \neq i$, the equilibrium prices and quantities for all other commodities would remain unchanged. However, neither e_{ji} nor e_{ij} can be expected to equal 0. Hence, the initial change in P_i will cause a shift in the demand curve for all other commodities (j). The resulting new equilibrium prices (P_j^1) and quantities (Q_j^1) are

$$(8) \quad Q_j^k = Q_j^{k-1}\{(1 + p_i e_{ji}) [1 - (1 - e_{sj}/e_{jj})^{-1}]\},$$

and

$$(9) \quad P_j^k = P_j^{k-1}(1 + p_i e_{ji})/(e_{sj} - e_{jj}),$$

where $k = 1$, $p_i = (P_i^k - P_i^{k-1})/P_i^{k-1}$, and $j = 1, \ldots, 22$ excluding $i, j \neq i$.

The changes in prices and quantities of j, i.e., commodities different from commodity i, cause a shift in the demand curve for commodity i unless $e_{ij} = 0$ for all j. The new equilibrium price and quantity for i is given by

$$(10) \quad Q_i^k = Q_i^{k-1}\{1 + \sum_{j=1}^{n} p_j e_{ij} [1 - (1 - e_{si}/e_{ii})^{-1}]\},$$

and

$$(11) \quad P_i^k = P_i^{k-1}\left[1 + \sum_{j=1}^{n} p_j e_{ij} (e_{si} - e_{ii})^{-1}\right],$$

where $k = 2$ and $p_j = (P_j^1 - P_j^o)/P_j^o$, $j \neq i$, $j = 1, \ldots, 22$ excluding i. This iterative procedure continues by replacing the current value of superscript k by $k + 1$ until a steady state is reached ($k = F$), i.e., equilibrium for price and quantity for all commodities. In the empirical analysis discussed later, the steady state for most commodities was reached for $k \leq 3$.

Having estimated the new market equilibrium, the model proceeds to estimate the distribution among strata of the quantity changes for each commodity. The final quantity of commodity j obtained by stratum m ($Q_{j(m)}{}^F$) is

$$(12) \quad Q_{j(m)}{}^F = N_{(m)} N^{-1} Q_{j(m)}{}^o [1 + p_i' e_{ji(m)} + p_j' e_{jj(m)}],$$

where $j = 1, \ldots, 22$ excluding i; $m = 1, \ldots, 5$, $i \neq j$, $N_{(m)}$ = number of consumers in stratum m, N = total number of consumers, and $P_i' = (P_i^F - P_i^o) / P_i^o$.

The final quantity of commodity i obtained per capita in stratum m ($Q_{i(m)}{}^F$) is given by

$$(13) \quad Q_{i(m)}{}^F = Q_{i(m)}{}^o\left[1 + \sum_{j=1}^{n} p_j' e_{ij(m)} + p_i' e_{ii(m)}\right],$$

where $j \neq i$.

The direct impact on per capita calorie $C_{i(m)}$ and protein $PR_{i(m)}$ intake in stratum m is estimated as

$$(14) \quad C_{i(m)} = [Q_{i(m)}{}^F - Q_{i(m)}{}^o]\, c_i,$$

where c_i = calorie content per unit of commodity i, and

$$(15) \quad PR_{(m)} = [Q_{i(m)}{}^F - Q_{i(m)}{}^o]\, pr_i,$$

where pr_i = protein content per unit of commodity i.

The indirect impact is

$$(16) \quad C_{j(m)} = \sum_{j=1}^{n} \left[Q_{j(m)}{}^F - Q_{j(m)}{}^o\right] c_j,$$

and

$$(17) \quad PR_{j(m)} = \sum_{j=1}^{n} \left[Q_{j(m)}{}^F - Q_{j(m)}{}^o\right] pr_j,$$

where $j \neq i$. The net impact is

$$(18) \quad C_m = C_{i(m)} + C_{j(m)},$$

and

$$(19) \quad PR_{(m)} = PR_{i(m)} + PR_{j(m)}.$$

Data Sources and Sample Characteristics

Data on quantities consumed and prices paid for each of twenty-two foods or groups of food

Table 1. Selected Descriptive Characteristics of the Sample Families

	Strata				
	I	II	III	IV	V
Income range ($/family/month)	0–42.4	42.5–56.5	56.6–113.0	113.1–169.5	169.6–up
Average family income ($/month)	29.44	56.39	89.49	161.41	382.33
Average per capita income ($/month)	4.99	8.95	13.16	25.62	58.82
Average per capita expenditures on food ($/month)	4.32	5.87	8.37	12.79	20.39
Income spent on food (%)	86.6	65.5	63.7	49.9	34.7
Number of families interviewed	46	42	80	32	30
Number of persons in families interviewed	270	264	544	201	200
Distribution of persons on strata (%)	18.3	17.8	36.8	13.6	13.5

as well as family incomes, size, and age distribution were collected from a sample of 230 families selected from the population of Cali, Colombia, using a stratified random sampling procedure. Each family was visited during February 1969, and again in August 1970.[3] For various reasons, about 30% of the families included in the first survey could not be included the second time. These families were replaced in the sample by randomly selected families living in the same part of town. Five strata were established on the basis of family incomes and the sample size for each stratum was proportional to the population among strata. Table 1 shows selected characteristics of the sample families.

Empirical Results

Income Elasticities and Budget Proportions

The income elasticity for each food was estimated for each of the five income strata on the basis of cross-section data within each stratum. The consumers within each stratum were faced with essentially the same price for any given food commodity. Furthermore, little variation in tastes and preferences was expected among consumers within a given stratum. Hence, the income elasticities were estimated simply by regressing per capital real income on per capita quantity consumed within each stratum. The estimated income elasticities were consistent with expectations. Foods of animal origin ("luxury goods") tended to have higher income elasticities than staple foods. All the foods showed a decreasing income elasticity for increasing incomes, becoming negative for certain staples in high income strata. The methodology used to estimate price elasticities is only valid for nonnegative income elasticities. Hence, where negative estimates did occur, a value of zero was used for estimating price elasticities, resulting in zero-value price elasticities.

Beef, accounting for 10%–12% of total incomes in all strata, was the largest single food expenditure for all strata. The budget proportion spent on most of the other food items decreases for increasing incomes. In addition to beef, basic grains, primarily rice, maize, and beans, account for a considerable amount of the consumer budget particularly in the low income strata. Tables showing income elasticities and budget proportions may be obtained directly from the authors.

Money Flexibility

Bieri and de Janvry report a number of estimates of the flexibility of money for various countries and time periods. These estimates range from −0.61 to −3.90. No such estimate

[3] The first survey was conducted by a Michigan State University marketing research team headed by Kelly Harrison. Upon completion of the project, the team kindly made data useful for the present study available to CIAT. The second survey was conducted by CIAT. Results of the MSU analyses and a detailed explanation of sampling procedures are reported by Riley et al.

was available for Cali or Colombia either for the population as a whole or by income strata.

Solving equation (1) for ϕ we get

$$\phi = \frac{E_i\,[1 - A_i\, E_i]}{e_{ii} + A_i\, E_i}. \tag{20}$$

The flexibility of money can be estimated on the basis of the income elasticity and the direct price elasticity for one good and the budget proportion spent on that good. No reliable estimate of price elasticities by income strata for Cali was available prior to this study. Hence, to estimate ϕ by income strata it was necessary first to estimate e_{ii} for at least one good for each income strata using an alternative method.

As explained above, data on quantity consumed, prices, and incomes were collected from the sample households for two points in time. Six highly standardized food commodities (rice, beans, tomatoes, oranges, sugar, and cooking oil) were chosen for a priori estimation of direct price elasticities. The change in quantity consumed and price for each of these foods between the two surveys and the change in incomes were estimated for each income strata. The change in quantity consumed was assumed to be due exclusively to changes in a product's own price and incomes.

The expected impact of income change on consumption was estimated on the basis of the income elasticity estimates from cross-section data and the remaining change in consumption was attributed to price change, thus providing an estimate of direct price elasticity. This procedure for obtaining a priori estimates of direct price elasticities is somewhat crude, primarily because no cross price effects were considered. However, we may assume that cross elasticities are small, although not zero. Hence, it was felt that the approximations of actual direct price elasticities provided by the procedure were sufficiently good—and certainly the best available, given the data constraints—for the purpose of estimating money flexibility. Furthermore, the fact that all a priori estimates fall within expected ranges for the particular commodities indicates considerable confidence in the method.

Using equation (20), the flexibility of money was estimated for each income strata as a simple average of the estimates obtained from each of the six food commodities (table 2). No significant difference of the estimated ϕ among strata was found.[4] The magnitude of ϕ as estimated here is similar to estimates from Chile for the period 1952–63 and the United States for the period 1923–41 and 1948–56, while it is considerably below estimates from Argentina and certain other countries (Bieri and de Janvry). In general, the estimated ϕ is below what would be expected on the basis of most previous estimates for other countries. Furthermore, the estimates are inconsistent with Frisch's conjecture that the absolute value of ϕ decreases as the level of real income increases. This study does not provide an acceptable explanation for this inconsistency but points out the need for additional empirical study on the relationship between ϕ and income levels within a given society. De Janvry, Bieri, and Núñez found a statistically significant fit when regressing estimates on ϕ from various countries and time periods on real incomes using a constant elasticity equation. However, such intercountry comparisons, although highly useful, suffer from the usual problems of choosing exchange rates that reflect real differences in purchasing power. Furthermore, intercountry differences in preferences not due to income levels are likely to influence marginal utility of money and the magnitude of the money flexibility. Hence, at equal real incomes, the money flexibility is likely to differ among countries. Correlation among countries, between preferences on the one hand and income levels on the other, may bias the results of intercountry comparisons.

Table 2. Estimated Money Flexibility Coefficients by Income Strata

Strata	Money Flexibility
I	−0.9445
II	−0.9878
III	−0.9619
IV	−1.0071
V	−1.0497
Sample mean	−0.9902

Price Elasticities

A complete price elasticity matrix was estimated for each stratum and for the market using equations (1), (2), and (3). The estimated direct price elasticities are shown in table 3.

[4] The 95% confidence limits for the sample mean were 0.8933 and 1.087. ϕ = 1.0 was used in all subsequent calculations.

Table 3. Estimated Direct Price Elasticities by Strata

	Strata					
Commodity	I	II	III	IV	V	Average[a]
Beef	−1.457	−1.305	−0.993	−0.692	−0.499	−0.839
Pork	−1.887	−1.608	−1.119	−0.823	−0.698	−1.011
Eggs	−1.343	−1.227	−1.262	−0.754	−0.349	−0.925
Milk	−1.788	−1.621	−1.121	−0.642	−0.201	−0.771
Rice	−0.426	−0.399	−0.397	−0.262	−0.187	−0.354
Maize	−0.630	−0.548	−0.441	−0.000	−0.000	−0.445
Beans	−0.812	−0.778	−0.649	−0.453	−0.251	−0.600
Lentils	−0.897	−0.903	−0.734	−0.620	−0.428	−0.641
Peas	−1.132	−1.128	−0.757	−0.585	−0.517	−0.698
Other grains	−0.869	−0.496	−0.389	−0.291	−0.253	−0.478
Potatoes	−0.410	−0.417	−0.312	−0.000	−0.000	−0.255
Cassava	−0.226	−0.279	−0.246	−0.000	−0.000	−0.187
Vegetables	−1.117	−0.986	−0.877	−0.379	−0.199	−0.685
Tomatoes	−1.169	−1.247	−0.997	−0.463	−0.278	−0.824
Plantain	−0.530	−0.486	−0.395	−0.000	−0.000	−0.376
Oranges	−1.389	−0.962	−0.789	−0.644	−0.293	−0.694
Other fruits	−1.293	−1.203	−0.847	−0.670	−0.500	−0.749
Bread and pastry	−0.651	−0.558	−0.327	−0.243	−0.000	−0.310
Butter and margarine	−2.792	−2.225	−1.499	−0.693	−0.395	−1.082
Sugar	−0.320	−0.296	−0.295	−0.203	−0.091	−0.245
Cooking oils and fats	−0.838	−0.814	−0.581	−0.298	−0.141	−0.507
Processed food	−1.850	−1.416	−1.295	−0.673	−0.430	−0.904

[a] Weighted average using total quantity consumed by strata as weights.

(Complete direct and cross price elasticity matrices may be obtained from the authors.) All estimates fall within expected ranges. As would be expected, the direct price elasticity for all goods increases for increasing income, and a considerable difference between the elasticity estimated for high income groups and that for low income groups was found for most commodities.

Nutritional Implications

The model shown by equations (6) through (19) was run for a hypothetical shift in the supply curve for each of the twenty-two commodities considered ($i = 1, \ldots, 22$), keeping the supply curves for the other twenty-one commodities constant. A horizontal shift in the supply curve equal to 10% of current supply of commodity i was arbitrarily selected, and the resulting net effects on protein and calorie intakes were estimated. No reliable estimates of the price elasticities of supply were available for the twenty-two commodities. It may be expected, however, that the supply elasticity is close to zero in the short run for most of the commodities, while it is likely to be larger but less than one for the intermediate and long run.[5] Supply elasticities equal to 0, 1, and 2 for all commodities were chosen for estimation. Although the absolute impact of a shift in the supply curve of a certain commodity on net calorie and protein intakes is sensitive to the magnitude of the supply elasticities, the relative impact among commodities does not depend greatly on the magnitude of the supply elasticities. Hence, since this study is primarily focused on relative impacts, the choice of supply elasticity is of little importance, as will be shown in the final part of the paper.

Indicators used to estimate the nutritional impact of shifting the supply curve of each of the commodities are the percentage of the total supply increase of commodity i consumed by nutrient deficient income strata, the change in per capita calorie and protein intake by deficient strata, and the percentage reduction in total calorie and protein deficiencies.

[5] The short run is defined here as the period not exceeding that occurring between production decision and the resulting impact on supply.

Table 4. Estimated Calorie and Protein Intakes and Deficit or Excess by Strata

	Strata					
	I	II	III	IV	V	Average
Estimated daily intake of calories per capita	1904	2119	2510	2831	3836	2552
Intake of requirements (%)[a]	89	99	117	132	178	119
Estimated daily intake of protein per capita (g.)	44.6	51.6	64.6	81.1	126.4	69.2
Intake of requirements (%)[a]	72	83	104	131	204	112

[a] Based on estimated requirements for Colombia (Williamson, Parra, and Téllez).

As shown in table 4, two of the five strata are deficient in protein and one is deficient in calories. Assuming that changes in nutrient intakes influence nutrition only if a nutrient deficiency exists—either before or after the change, increased or decreased protein and calorie intake influences nutrition if it occurs in strata I and II and stratum I for protein and calories, respectively. Changes in protein and calorie intakes in other strata will influence nutrition only if the changes result in deficiencies.

The average daily per capita intake of calories and protein for the sample as a whole was estimated to be 119% and 112% of requirements (table 4). Hence, no additional food would be needed to fulfill calorie and protein requirements if available food were distributed according to needs. This situation clearly points out the inadequacy of average data as a measure of nutritional status.

Table 5 shows the proportion of the supply increases obtained by deficient strata. As might be expected, a relatively small proportion of an increase in the supply of meats, eggs, milk, and certain grain legumes would be consumed by protein and calorie deficient groups. Hence, efforts to improve human nutrition through the expansion of the supply of these commodities would entail a considerable "waste" of nutrients. For example, 71% of the protein generated from an increase in beef

Table 5. Percent of Supply Expansion Expected to be Consumed by Calorie and Protein Deficient Strata

	% of Increase Consumed by	
Foods for Which Supply Is Increased	Calorie Deficient Strata	Protein Deficient Strata
Beef	12.1	28.7
Pork	11.1	29.4
Eggs	12.5	32.1
Milk	12.0	28.7
Rice	20.2	40.3
Maize	27.8	54.7
Beans	19.1	42.2
Lentils	7.9	21.9
Peas	8.0	22.1
Potatoes	27.5	58.8
Cassava	30.4	62.9
Vegetables	19.5	40.3
Tomatoes	21.1	40.6
Plantain	25.7	55.3
Oranges	12.4	29.4
Bread and pastry	25.0	50.2
Sugar	20.1	37.6
Oils and fats	17.2	39.3

Table 6. Change in Per Capita Calorie Intakes Caused by a 10% Increase in the Supply of Any One of the Foods for $Es = 0$

Foods for Which Supply Is Increased	Deficient Strata			Nondeficient Strata		
	Direct	Indirect	Net	Direct	Indirect	Net
Beef	14.56	−6.49	8.07	23.65	0.99	24.64
Milk	6.17	−3.04	3.13	10.14	0.37	10.51
Rice	36.10	6.89	42.99	31.82	−1.03	30.79
Maize	38.21	0.07	38.28	22.24	−2.22	20.02
Beans	7.77	0.29	8.06	5.27	−0.01	5.26
Peas	0.23	−0.67	−0.44	0.59	0.16	0.75
Potatoes	10.86	4.21	15.07	6.38	−2.63	3.75
Cassava	17.29	5.79	23.08	10.07	−11.16	−1.09
Vegetables	2.57	−1.62	0.95	2.36	0.27	2.63

production would be wasted in a nutritional sense, while this would be true only for 58% of the protein from additional bean production.

The direct, indirect, and net effects on per capita calorie and protein intakes for deficient and nondeficient strata are shown in tables 6 and 7. To save space, only the estimates obtained for supply elasticity equal to 0 are shown. It should be noted that the net effect decreases for increasing supply elasticity. (Only a few commodities are shown; estimates for all the commodities may be obtained from the authors.)

The net effect is determined by the increase in consumption of the food for which the supply curve was shifted (i)—the direct effect—and the resulting adjustment in the consumption of all other foods (j)—the indirect effect. Hence, the net effect is estimated as the sum of the changes in consumption of all foods, brought about by a shift in the supply curve of one of these foods.

The net impact on per capita calorie intakes among calorie deficient strata is relatively high for basic staples such as cassava, maize, and rice, while beef, maize, and rice provide the largest impact on per capita protein intake among deficient groups. The nutritional waste associated with an increase in the supply of meats, milk, lentils, peas, tomatoes, and fruits is illustrated by the greater increase in per capita calorie and protein intakes among nondeficient groups. However, in spite of the waste, a certain percentage increase in beef supply provides a larger net impact on protein intake among protein deficient groups than an equal percentage increase of any other single food. The large negative indirect effects within deficient strata associated with increases in the supply of certain foods is a result of high direct price elasticities for these foods (absolute value in excess of one), severe budget constraints, and relative nutrient contents. When the supply of one of these foods increases, total consumer outlay for the food increases. Since a large portion of the household budget is already committed to food, outlays for other foods tend to decrease as reflected by cross elasticities, the net result being a smaller nutritional impact than that

Table 7. Change in Protein Intakes (G./Capita) Caused by a 10% Increase in the Supply of Any One of the Foods for $Es = 0$

Foods for Which Supply Is Increased	Deficient Strata			Nondeficient Strata		
	Direct	Indirect	Net	Direct	Indirect	Net
Beef	1.41	−0.15	1.26	1.98	0.07	2.05
Milk	0.42	−0.08	0.34	0.59	0.04	0.63
Rice	0.79	0.16	0.95	0.66	−0.07	0.59
Maize	0.94	−0.02	0.92	0.44	−0.09	0.35
Beans	0.57	0.01	0.58	0.44	0.00	0.44
Peas	0.06	−0.02	0.04	0.13	0.01	0.14
Potatoes	0.24	0.06	0.30	0.10	−0.10	0.00
Cassava	0.09	0.05	0.14	0.04	−0.35	−0.31
Vegetables	0.10	−0.03	0.07	0.08	0.02	0.10

reflected by the increase in the supply of a certain food. Increasing the supply of certain foods may actually reduce total protein and calorie intakes among deficient groups because the absolute value of the negative indirect effect exceeds the direct effect. Increasing the supply of peas and tomatoes was found to reduce total calorie intake by deficient groups, while protein intakes would decrease by increasing supplies of oils and fats.

The actual reduction in calorie and protein deficiencies that can be expected from supply expansions of the magnitude considered here are small (table 8). If supply elasticities are equal to 0, a 10% increase in the production of maize or rice would reduce calorie deficiencies by 16%–18% and protein deficiencies by 8%–9%. A similar percentage increase in beef production would reduce protein deficiencies in strata I and II by 6% and 15%, respectively. As supply elasticity increases, the nutritional impact of a shift in the supply curve diminishes. If supply elasticities are equal to one, a 10% increase in the production of maize or rice would reduce calorie deficiencies by 5%–6% and protein deficiencies by 2%–4%.

In view of the fact that the quality of protein consumed plays a major role in determining the nutritional level, it was attempted to analyze the impact on the intake of the three essential amino acids, lysine, methionine, and trytophan. It was found, however, that the diets contained more of these amino acids than required at all income levels. Hence, for the family as a unit, it appears that quantity of protein is more important than quality for the population studied. However, an analysis of the intrafamily food distribution is required to determine the relative scarcity of quantity versus quality of protein among the most vulnerable groups: infants, young children, and pregnant women.

Table 8. Reduction in Calorie and Protein Deficiencies Caused by a 10% Increase in the Supply of Any One of the Foods for $Es = 0$ (% of Total Deficiency)

Food for Which Supply Is Increased	Calories Strata I	Protein Strata I	Protein Strata II
Beef	3.42	5.75	14.71
Pork	1.00	1.32	4.23
Eggs	0.33	1.21	3.46
Milk	1.33	1.49	4.13
Rice	18.22	5.80	8.56
Maize	16.22	5.46	8.65
Beans	3.42	2.99	6.15
Lentils	0.48	0.52	1.73
Peas	−0.19	0.17	0.48
Potatoes	6.39	2.24	2.02
Cassava	9.78	1.90	−4.48
Vegetables	0.40	0.29	0.77
Tomatoes	−0.15	0.00	0.01
Plantain	9.64	1.15	1.63
Oranges	0.86	0.75	0.77
Bread and pastry	5.29	2.07	3.46
Sugar	17.64	1.44	0.87
Oils and fats	8.55	−0.11	−0.29

Utility for Establishing Commodity Priorities

The empirical findings of this study clearly point out that relative increase in total nutrient supply is a poor indicator of relative nutritional impact. The nutritional waste defined earlier differs considerably among commodities. Furthermore, the adjustment in the consumption of foods, other than the one for which supply is increased, is of considerable importance in determining the final nutritional implications.

In addition to the relative nutritional impact, as estimated here, the relative cost of research, policy, and related activities needed to facilitate the supply expansion must be estimated in order to establish commodity priorities with highest nutritional impact per unit of resource invested in such activities. Changes in production costs need not be considered here since they will be reflected in the supply elasticity, which in turn participates in determining the new market equilibrium.[6]

While the research and policy costs are to be estimated for each individual project, three alternative cost assumptions are made here to illustrate how the information presented may complement estimated research and policy costs in establishing commodity priorities. The three assumptions are that (*a*) an equal percentage increase in the supply of any one of the foods considered can be obtained at equal costs, (*b*) an equal increase in the supply of any one of the foods measured in terms of quantity (weights) of the food can be obtained at equal costs, and (*c*) a given amount of calories and protein, respectively, can be supplied from any one of the foods at the same

[6] Since this analysis considers only one goal, improved human nutrition, the implications for other possible goals such as the distribution of benefits between consumer and producer sectors and among production factors are not discussed here. For a discussion of these relationships, see Ramalho de Castro and Schuh.

Table 9. Suggested Commodity Priorities if Improved Calorie Nutrition Is the Goal

Order of Priority	Cost Assumption (*a*) $E_{si} = 0$	Cost Assumption (*a*) $E_{si} = 1$	Cost Assumption (*b*) $E_{si} = 0$	Cost Assumption (*b*) $E_{si} = 1$	Cost Assumption (*c*) $E_{si} = 0$	Cost Assumption (*c*) $E_{si} = 1$
1	Rice	Rice	Oilseed	Oilseed	Cassava	Potatoes
2	Sugarcane	Maize	Sugarcane	Maize	Potatoes	Cassava
3	Maize	Sugarcane	Maize	Rice	Maize	Maize
4	Cassava	Plantain	Rice	Beans	Plantain	Plantain
5	Plantain	Oilseed	Wheat	Wheat	Sugarcane	Beans

costs. The commodity priorities for each of the assumptions are shown in tables 9 and 10, for supply elasticities equal to 0 and 1. The priorities are established on the basis of relative reduction in calorie and protein deficiencies expected from the increase of the supply of any one of the commodities, where the supply increases correspond with the above three alternative assumptions. The underlying numerical estimates are shown for assumption (*a*) only (table 8).

Depending on the relative costs of research and policy measures needed to facilitate supply expansions among the various commodities, this analysis shows that rice, oilseed, cassava, and potatoes would provide the most effective means for improving calorie nutrition in the population studied and beef, beans, and maize would be most effective in meeting protein nutrition goals. Maize appears among the five priority commodities for all costs assumptions and supply elasticities, whether calorie or protein nutrition is the goal. Hence, under any of the cost assumptions considered here, it appears that high research and policy priority should be placed on that commodity if both calorie and protein nutrition are goals.

As the supply elasticity increases, expanding supplies of commodities with high absolute direct price elasticities such as beef and to a lesser extent beans become more important in fulfilling nutritional goals, while expanding supplies of commodities with low absolute price elasticities such as cassava become less important. This phenomenon is explained by the sharper price drop of commodities with high absolute price elasticity of demand and the resulting larger quantity response to the magnitude of the supply elasticity. However, the magnitude of the supply elasticity does not greatly influence relative commodity priorities.

Final Comments

The present analysis has attempted to demonstrate how economic analysis may provide guidelines for establishing commodity priorities in agricultural research and production-oriented public policy if improved human nutrition for the urban population is a goal.[7] The analysis assumes that the expanded food supply resulting from the research and policy activities is in excess of increases in food demands at current prices caused by factors such as increased consumer incomes and population, i.e., such demand increases are expected to be fulfilled in the absence of the proposed activities. If this is not the case and research and public policy is needed partly to meet

[7] Although not treated in this article, implications for human nutrition among the rural population may be equally or more important and offers, in our opinion, another highly disregarded but potentially rewarding area of economic study.

Table 10. Suggested Commodity Priorities if Improved Protein Nutrition Is the Goal

Order of Priority	Cost Assumption (*a*) $E_{si} = 0$	Cost Assumption (*a*) $E_{si} = 1$	Cost Assumption (*b*) $E_{si} = 0$	Cost Assumption (*b*) $E_{si} = 1$	Cost Assumption (*c*) $E_{si} = 0$	Cost Assumption (*c*) $E_{si} = 1$
1	Beef	Beef	Beans	Beans	Maize	Maize
2	Rice	Maize	Wheat	Beef	Rice	Rice
3	Maize	Rice	Maize	Wheat	Wheat	Wheat
4	Beans	Beans	Rice	Maize	Beans	Beans
5	Potatoes	Potatoes	Beef	Rice	Eggs	Eggs

demand increases at current prices, the present analysis would apply only to the supply expansion in excess of demand expansions at current prices.

It appears from the empirical analysis that the problem of malnutrition in the population studies is basically one of absolute poverty among certain groups. While new technology resulting in shifts in the supply curve and reduced prices are important to improve human nutrition, the full potential of such technology for improving human nutrition is reached only if accompanied by rapid increases in incomes among low income consumers. Available quantities of food were estimated to be sufficient to provide an adequate calorie and protein diet for all sample members. Yet, even when using average family data, considerable deficiencies were identified. It is likely that much more severe deficiencies would have been detected if data were obtained on intrafamily food distribution.

Even though malnutrition in many cases might be reduced or eliminated through a more even distribution of incomes and/or food, such redistribution is likely to be slow at best and it appears that improved information on nutritional implications of alternative agricultural production research and policy measures may contribute to improved human nutrition even in the absence of such redistribution.

The authors of this article do not suggest that improved nutrition be the sole goal of agricultural research. We do suggest, however, that there exists an urgent need for developing and empirical testing of methodology useful to assist in establishing commodity priorities in research and public policy where improved human nutrition is one of the final goals. It is hoped that this analysis provides a modest contribution to such efforts.

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Peasants' Response to Modernization Projects in *Minifundia* Economies

Carlos A. Benito

Different factors are mentioned in explaining peasants' adoption of modern technologies. A model of the peasant household is developed integrating most of these factors, condensed into a stochastic linear programming framework, and applied to the Puebla area in Mexico. Observed low adoption rates and peasants' participation in modernization projects are explained by opportunity costs of time and uncertainty. The view that labor-using technologies per se will rapidly increase agricultural production is challenged. The generation of less risky technologies and more emphasis on organizational-communication aspects are also necessary. Further rural development will require intermediate technologies and organizations.

Key words: adoption, allocation of human time, information, organizational activities, safety-first rule.

An important question in appraising rural development modernization projects is: what are the factors explaining the rate of adoption of the recommended technical practices? Researchers from various fields of the social sciences have been observing and explaining patterns of adoption among peasants under different socioeconomic structures. Principal explanations have related to the fundamental behavioral rule of peasant families, e.g., motivation in general (Chayanov, Lipton, Schultz) and behavior under uncertainty (Moscardi, O'Mara, Roumasset); the admissible set of opportunities for the peasant family, e.g., within the household (Hymer and Resnick, Sen) or in relation to village or community (Cancian); and the dynamics of communication and social group formation (Rogers, Diaz and Felstenhausen).

The proposition of this paper is that most of these explanatory factors can be consistently integrated into a choice model. Empirical research about the Puebla area in Mexico demonstrates that this model can represent the anthropological content of peasant household units acting within *minifundia* types of socioeconomic structures, i.e., part-time farming within small holdings combined with labor market activities.[1] The process of community organization used by modernization projects like the Puebla Project in Mexico (e.g., the formation of credit groups) is also represented by such a model.

The Puebla Project is a modernization project devised as a strategy for rapidly increasing yields of maize among small holders (CIMMYT). Operationally, it is a package of technological recommendations and organizational practices reducible to the following components: technical information about the optimal use of fertilizer to produce maize, a time schedule for fertilizer application, guidance concerning plant density, a suggested procedure for facilitating access to the fertilizer market, and a procedure for obtaining access to credit. The first three items comprise a technological package geared to increase corn yields, while the last two integrate the organizational element. In the Puebla Project, fertilizer and credit are tied sales because credit is given to participants for the specific purpose of buying fertilizers.

After seven years of experience with the Puebla Project, one of the best-controlled experiments in modernization, the rates of adoption of recommended technologies still are relatively low (table 1). This is a puzzle for

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[1] The center and southern regions of Mexico are here described as a *minifundia*-type structure. The structure has been institutionalized by the agrarian reform resulting from the Mexican Revolution. Its specific forms are the *ejido* and the "small property."

Table 1. Number of Farmers on Credit Lists and Areas of Maize for Which Credit Was Received, Puebla, Mexico, 1968–73

Year	Number of Farmers	% of Total[a]	Area (ha.)	% of Total[b]
1968	103	0.2	76	0.1
1969	2,561	5.9	5,838	7.3
1970	4,833	11.1	12,601	15.8
1971	5,240	12.1	14,438	18.0
1972	6,202	14.3	17,533	21.9
1973	7,194	16.6	20,604	25.8

Source: Centro Internacional de Mejoramiento de Maiz y Trigo.
[a] Based on a total of 43,300 farmers.
[b] Based on a total of 80,000 ha. of maize.

policymakers and social scientists who, assuming the existence of "surplus labor," investigate the diffusion of labor-intensive practices within subsistence economies. A solution to this puzzle is all the more necessary in the face of the high priority that various international agencies (e.g., the International Bank for Reconstruction and Development, international research centers, etc.) and national agencies are giving today to modernization projects as a frontal attack on the world food problem.

A methodological proposition of this paper is that reduced-form models and one-modal explanations of adoption are insufficient to investigate that puzzle. What is necessary is a structural form representation of the peasant household economy that could incorporate the various factors that explain adoption.

One of the major results of this study is to show that modern technologies will be adopted by peasants at a low rate when the opportunity cost of their time in the labor market is relatively high. This will be true when the recommended technology is labor using and when access to modern input and credit markets is through a community organization process that is also time consuming. Although the model shows that peasants with larger holdings will adopt at a faster rate, an explanation is also provided for the paradox observed by several researchers that some groups of peasants with smaller holdings evidence the highest rates of adoption (Cancian, Peters). The risky nature of agricultural production and labor earnings in a subsistence economy is also represented. When the behavior of peasants under uncertainty and imperfect information is introduced into the model, an additional explanation for different patterns of adoption among peasants is found.

The remainder of this paper presents a description of the model developed in this study and its application to the Puebla Project. First, the major components of the structural form of a model of the peasant household economy are developed. Next, the model is condensed into a linear programming version in which risk, uncertainty, and information are incorporated by means of a safety-first rule. Then, by means of plausible assumptions and simplifications, an otherwise dynamic and nonlinear model is transformed into a simpler linear model so that the linear programming algorithm may be used to obtain solutions. Finally, this model is applied to the case of the Puebla Project in Mexico with results that explain the relatively low diffusion rates observed in the Puebla area during the first seven years of the modernization project. (A more expanded version of this study has been developed in Benito 1974).

A Model of the Peasant's Household

The Peasant's Economy within the Traditional Village

The total available time of the peasant household, s, is allocated between agricultural activities, s_a, nonagricultural working activities, s_w, and other household activities, s_h:

$$(1)\ s - s_a(t) - s_w(t) - s_h \geq 0,\ t_0 \leq t \leq t_1.$$

Agricultural time, s_a, is allocated in proportion, π_a, to farming, in proportion, π_k, to learning and gathering information about modern agricultural practices, and in proportion, π_o, to organizational activities:

$$(2)\ \pi_a(t) + \pi_k(t) + \pi_o(t) = 1,\ t_0 \leq t \leq t_1.$$

The last two types of activities are open to peasants through modernization projects. Nonagricultural working activities include self-employed activities (crafts, trade, etc.) and working in the labor market. From here on, the paper will concentrate on labor market activities alone.

The set of feasible agronomic practices is represented by the following stochastic production function:

$$(3)\ Y(t) = G_a\,[s_a(t)\cdot\pi_a(t),\ x_a(t),\ C_a(t),\ C_k(t),\mu\,(t)].$$

The concave function, $G_a(\cdot)$, expresses expected agricultural production, Y, as a positive function of labor time, $s_a\pi_a$; agroinputs, x_a; services from physical capital, C_a; services from human capital, C_k; and a stochastic factor μ (e.g., weather). The introduction of services from human capital (i.e., knowledge and information of agricultural practices) transforms the technology into an endogenous variable. Low levels of human capital indicate knowledge (in some abstract units) of only "traditional" practices, while high levels indicate knowledge of "modern" practices.

The total labor time allocable to farming activities is constrained by the availability of other resources, mainly land size, C_a, and by the over-all nature of the technology (in this case, a labor-intensive technology).

The agricultural production Y can either be sold in the proportion θ_m at price p_m or consumed by the peasant family in the proportion θ_c:

(4) $Z_a(t) \leq Y(t)\theta_m(t)p_m(t),\ t_0 \leq t \leq t_1,$

and

(5) $\theta_c(t) = 1 - \theta_m(t),\ t_0 \leq t \leq t_1,$

where Z_a represents sales of agricultural products. The degree of commercialization, θ_m, is determined at each point in time according to the motivation and structure of the peasant family as well as market conditions.

Earnings generated in the labor market, Z_w, are represented by

(6) $Z_w(t) = s_w(t) \cdot g_w[C_w(t)],\ t_0 \leq t \leq t_1,$

where the supply wage rate $g_w(\cdot)$, is an endogenous variable in the long run, since workers can increase it by investing in on-the-job experience, C_w. Occupational opportunities outside the farm are subject to

(7) $s_w(t) \leq g_e[C_w(t)],\ t_0 \leq t \leq t_1,$

indicating that the peasant's employment opportunities, $g_e(\cdot)$, in the labor market are limited, although in the long run they can be enhanced through investment in on-the-job experience.

Development through Modernization Projects

The economic performance of the peasant household depends both on the wealth of the individual household and its village social power. The peasant household wealth at each time t is integrated by the accumulated physical capital, C_a, and the embodied human capitals, C_k and C_w. The village social power, C_o, determines the accessibility of the peasantry to modern input, output, and credit markets.

Modernization projects promote the adoption by peasants of new practices and modern inputs through new knowledge and information and organizational help. Acquisition of new knowledge and information for a peasant represents an investment in human capital, $\partial C_k/\partial t$. Organizational help facilitates the formation of credit groups (*grupos solidarios*) that increase the social power of the peasantry, $\partial C_0/\partial t$. The *grupos solidarios* enhance the financial liability of this social group and provide an organizational structure which facilitates its accessibility to the modern inputs and credit markets:

(8) $x_a(t) \leq G_x[C_0(t)],\ t_0 \leq t \leq t_1,$

and

(9) $B(t) \leq G_b[C_0(t)],\ t_0 \leq t \leq t_1,$

where $G_x(\cdot)$ and $G_b(\cdot)$ are marketing and financing functions, respectively, and B is credit received from banks.

The major investment cost involved in learning and becoming organized is the opportunity cost of the human time of each peasant household. However, a more detailed study of the adoption problem will require a specification of the social process of group formation (Benito).

Motivations of the Peasant Household

An empirical premise of this study is that the peasant household allocates its human time and the market products so as to maximize the discounted utility, $F(\cdot)$, of expected consumption, Z_c, of purchased goods and home-grown food:

(10) $\max W_0 = \int_{t_0}^{t_1} F[Z_c(t)] \exp\left[-\tau(t - t_0)\right] dt,$

subject to the survival constraint (Lipton, Moscardi)

(11) $P[Z_c(t) \geq Z^*_c] \geq (1 - \alpha),\ t_0 \leq t \leq t_1,$

where τ is the subjective rate of time preference, $P[\cdot]$ indicates probability, Z^*_c is a minimum subsistence level that is biologically and culturally determined, and α is the subjective probability of disaster.

For the special case when $\alpha = 0$ and the subsistence constraint is effective (i.e., $Z_c = Z^*_c$), the conditions of "pure subsistence behavior" are determined. This can be interpreted as in the case of a peasant economy described by Chayanov and some anthropologists (Wolf). In this case of pure subsistence behavior, besides the utility $F(\cdot)$ that a peasant assigns to a given level of consumption, he will also attach to it the utility of survival.[2] In this situation there is an incentive for faster adoption of new technologies and, hence, an answer to the puzzle investigated by Cancian and observed in the Puebla area by Peters—that very small farmers can be faster adopters than medium-size farmers.

A Linear Stochastic Model of Peasant Households

A Linear Programming (LP) Model

The basic features of the above model can be condensed into a linear model. It is assumed that the allocation of time between working activities, $s_a + s_w$, and other household activities, s_h, has already been determined, and the model concentrates on the investigation of the time allocation between working activities. In addition, it is assumed that the utility function is linear in expected consumption and that expected consumption is a monotonically increasing function of full expected income H. This is a plausible assumption with regard to peasants with earnings close to subsistence levels. Furthermore, the peasant's household behavior under uncertainty and under different degrees of information is represented by a safety-first rule (Telster):

$$(12)\quad \max H = F(\cdot) + q_{w1}\Delta C_{w1}, \quad \text{subject to } P[F(\cdot) \geq Z^*_c] \geq (1 - \alpha),$$

where q_{w1} is the demand price of one unit of investment in on-the-job experience and ΔC_{w1} is this investment in human capital.

The demand price of human capital is an exogenous variable in this LP model. This specification transforms a multistage control problem into a simpler one-stage programming case. The certainty equivalence of the above formulation is

$$(13)\quad \max H, \text{ subject to } P[F(\cdot) - \eta_\alpha \sigma^*_f] \geq Z_c,$$

where η_α is a cumulative distribution function of total income and σ^*_f is perceived standard deviation of total income. The value of η_α is estimated from a standard normal table.

The empirical model represents the economy of an "average" peasant household in Puebla, Mexico, which produces only maize. A complete LP tableau is formulated in table 2.

Maize production can be generated by means of two activities: a traditional agronomic practice labeled with the subindex t and a modern practice recommended by the Puebla Project identified by the subindex m. There also exist two major job opportunities depending on the previous level of investment in human capital: job 1, a permanent type of job, subject to a minimum demand constraint, $g_{min}{}^1$ (row 9), and job 2, a temporary job subject to a maximum demand constraint, $g_{max}{}^2$ (row 10). Job 1 pays a higher wage rate than job 2 and, in addition, generates on-the-job experience that is measured by the time worked in job 1, i.e., $\Delta C_{w1} = s_{w1}$.[3]

The value B of constraint (11) measures the level of the peasant's savings that can be used to buy fertilizer. The funds that he can borrow from banks or from other credit institutions depend on the time that he allocates to organizational activities, s_o (column 11). The level of s^*_o, determined by the optimal solution of the LP model, will be a proxy for the peasant's "participation" in the Puebla Project.

Farm income is the only stochastic variable considered in this model. Based on a priori information, it is assumed that yields from traditional farming and modern farming are closely related, since both are subject to the same ecological conditions. For analytical simplicity, their correlation coefficient is assumed to be positive and one. These assumptions, which are plausible for the case of the Puebla area, transform a nonlinear programming model into the much simpler case of a linear programming model.[4]

[2] When the constraint is effective, the Lagrangian multiplier representing the marginal utility of survival becomes positive. Therefore, in the behavioral rule (first-order condition) of the peasant's demand for agronomic inputs x_e, the benefits of production are also weighed by this marginal utility of survival (Benito).

[3] One limitation of introducing a minimum constraint, $g_{min}{}^1$, is that the peasant may be forced to seek permanent employment under all circumstances. One wants this lower bound constraint to operate only in the event that the permanent job is considered and zero otherwise. This will require an integer LP algorithm to solve. However, this theoretical limitation did not affect the empirical study for two reasons: it was a binding constraint and the peasant was considered to have only one job alternative (permanent or temporary).

[4] If the assumption that a correlation coefficient equals 1 was not met, the specification used in the LP model will give an upward bias in the estimated standard deviation.

Table 2. Tableau for the Linearized Peasant Family Model

Constraints			Farming Activities							Labor Market Activities			Project Participation	Perceived Deviations	
			Technology Traditional	Technology Modern	Total Output	Farming Monetary Costs				Supply Labor 1	Learning	Supply Labor 2	Organizing	Traditional	Modern
Concept	Value	Type	C_a^t	C_a^m	Y	x_n	x_{ph}	x_p	x_f	s_{w1}	ΔC_{w1}	s_{w2}	s_o	C_a^t	C_a^m
			1	2	3	4	5	6	7	8	9	10	11	12	13
Objective function	Maximize		0	0	p_a	$-p_n$	$-p_{ph}$	$-p_p$	$-p_f$	w_1	q_{w1}	w_2	0	0	0
1. Maize output (kg)	0	=	y_t	y_m	-1										
2. Family time (days/year)	s	≥	a_{ts}	a_{ms}						1		1	1		
3. Land (ha.)	C_a	≥	a_{tl}	a_{ml}											
4. Nitrogen (kg)	0	=	a_{tn}	a_{mn}		-1									
5. Phosphate (kg)	0	=	a_{tph}	a_{mph}			-1								
6. Plants (thousands)	0	=	a_{tp}	a_{mp}				-1							
7. Fixed cost/ha.	0	=	a_{tf}	a_{mf}					-1						
8. On-the-job experience	0	=								1	-1				
9. Minimum supply to job 1 (permanent job)	g_{min}^1	≤								1					
10. Maximum supply to job 2 (temporary job)	g_{max}^2	≥										1			
11. Credit availability	B	≥				p_n	p_{ph}						$-b$		
12. Safety-first rule	Z^*_r	≤			p_a	$-p_n$	$-p_{ph}$	$-p_p$	$-p_f$	w_1		w_2		$-\eta\sigma^*_{at}$	$-\eta\sigma^*_{am}$
13. Combination constraint, σ_t^*	0	=	1											-1	
14. Combination constraint, σ_m^*	0	=		1											-1

Empirical studies indicate that the observed distributions of corn yields in the Puebla area are normal (CIMMYT). It is assumed that the peasant knows from experience both the form of the distribution, i.e., normality, and its two first moments, the mean and the standard deviation.

Finally, the model distinguishes between the perceived (or subjective) distribution of probabilities and the observed (or objective) distribution of probabilities for each activity, i.e.,

$$\sigma^* = \beta\sigma, \tag{14}$$

where σ is the (objective) standard deviation "observed" by researchers, σ^* is the (subjective) standard deviation "perceived" by the peasant, and β is the degree of information of the peasant, which can be $\beta = 1$ when he has complete information or $\beta > 1$ when he has incomplete information.

In the empirical analysis of the study, it is assumed that the perception of the standard deviation of yields from traditional farming coincides with the observed. The justification for this assumption is that through long experience a peasant has gathered sufficient information to know what is the actual standard deviation. However, based on previous empirical studies (Villa Issa) and personal observations, it is assumed that the perceived standard deviation of maize yields from modern technology is higher than the one observed in the agronomic experiments conducted by the Puebla Project team.

Solution of the Linearized Model

Table 3 presents the empirical information for the solution of the model. Once an optimal solution is obtained for the LP model of the average peasant family, the quantitative changes in adoption rates are investigated for two major cases, first, when the physical and human capital endowment of the family is different from that of the average case, e.g., different size of landholdings and/or different job opportunities, and, second, when for a given family with permanent job opportunities the displacement of the equilibrium is studied when the wage rate changes. This is valuable information for designers and managers of modernization projects.

Case 0 of table 4 presents the results of the optimal solution of the LP model. The average peasant family will adopt the modern technology but only partially; 40% of the land will be cultivated in accordance with the Puebla Project recommendations, while the remainder remains under traditional methods. Subsistence income is a bounding constraint, and the peasant will opt for (technical) diversification. An alternative interpretation is that the peasant will utilize a technique that represents a

Table 3. Empirical Information for an Average Peasant Family, Puebla, 1971–72[a]

Constraints			Farming Activities							Labor Market Activities			Project Participation	Perceived Deviations	
			Technology Traditional	Technology Modern	Total Output	Farming Monetary Costs				Supply Labor 1	Learning	Supply Labor 2	Organizing	Traditional	Modern
Concept	Value	Type	C_a^t	C_a^m	Y	x_n	x_{ph}	x_p	x_f	s_{w1}	ΔC_{w1}	s_{w2}	s_o	C_a^t	C_a^m
			1	2	3	4	5	6	7	8	9	10	11	12	13
Objective function (pesos)	Maximize		0	0	0.92	−4.48	−3.17	−0.30	−30	36	5	25	0	0	0
1. Maize output (kg)	0	=	2,000	3,500	−1										
2. Family time (days/year)[b]	450	≥	41	53						1		1	1		
3. Land	2.5	≥	1	1											
4. Nitrogen (kg)	0	=	22	115		−1									
5. Phosphate (kg)	0	=	15	40			−1								
6. Plants (thousands)	0	=	33	60				−1							
7. Fixed cost/ha.	0	=	1	1					−1						
8. On-the-job experience (days)	0	=								1	−1				
9. Minimum supply to job 1 (permanent job)	300	≤								1					
10. Maximum supply to job 2 (temporary job)	280	≥					1					1			
11. Credit availability (pesos)[c]	450	≥				4.48	13.17						−80		
12. Safety-first rule (pesos)[d]	10,000	≥			0.92	−4.48	−3.17	−0.30	−30	36		25		−330	−1,520
13. Combination constraint, σ^*_t	0	=	1											−1	
14. Combination constraint, σ^*_m	0	=		1											−1

Sources: Based on Centro Internacional de Majoramiento de Maiz y Trigo and Luis A. Villa Issa.

[a] The input-output coefficients refer to one ha./year.

[b] For a six-member family.

[c] The constraint represents the family-owned funds.

[d] For $\alpha = 0.15$ and, therefore, $n_\alpha = 1$.

combination of the traditional and modern practices (table 5).

As the peasant's savings are not sufficient to cover the recommended fertilizer expenditures, he joins a solidarity group allocating a full five days to organizational activities.

Case 1 of table 4 shows that, if the peasant's perception of risk coincides with the observed risk of modern utilization practices, e.g., $\sigma^*_{am} = \sigma_{am} = 760$, his adoption rate will be higher than in case 0. A different pattern of allocation of resources is generated because the safety-first rule no longer is a bounding constraint. The peasant now perceives modern practices as a more profitable activity, and he allocates more time to organizing activities in order to obtain more credit. The difference in net income between cases 1 and 0, i.e., 1,325 pesos, is the household's value of agronomic information (Gould).

Case 2 of table 4 shows that, if the peasant possesses 3.5 hectares of land rather than 2.5 hectares but all other conditions presented for case 0 are maintained, the rate of adoption of modern technology will increase. But still subsistence income is binding; 86% of the land is cultivated under modern practices and the remaining 14% with traditional practices. Under these circumstances, there will be no unemployment. Also, more time will be allocated to farming resulting from the increased size of the holding, the use of modern labor-intensive technology, and a considerable amount of time devoted to organizational activities.

Case 3 of table 4 presents the case of a peasant household whose members have access to permanent jobs. In this case the family's unemployment rate drops to zero. The subsistence constraint is not binding, and the household cultivates all of its land with modern technology and participates in organizational activities 3% of the time in order to obtain credit. The allocation of time to and the output from agricultural activities are the same as for case 1.

The supply of labor response to wage rate changes was studied by means of sensitivity analysis. Variations of the wage rate within the range of 20 pesos and 36.50 pesos will not affect the quantity of labor supplied to job 1. But since the observed average wage rate of permanent jobs is about 36 pesos, peasants with slightly better job opportunities (i.e., with wage rates equal to or higher than 36.50 pesos) will have fewer incentives to work on the farm and, *ceteris paribus*, to participate in the modernization project. This result challenges the effectiveness of labor-using technologies per se.

Table 4. Linear Programming Optimal Solutions of the Peasant Household Economy, Puebla, 1971–72

Variable	Case 0[a]					Case 1[b]					Case 2[c]					Case 3[d]				
	Total for 2.5 ha.			%	Per ha.	Total for 2.5 ha.			%	Per ha.	Total for 3.5 ha.			%	Per ha.	Total for 2.5 ha.			%	Per ha.
		1		2	3		4		5	6		7		8	9		10		11	12
Allocation of human time (days)																				
Farming	62					0					22					0				
Traditional	52					133					157					133				
Modern			114	25	46			133	30	53			179	40	51			133	30	53
Labor market																303				
Job 1	280					280					252					0				
Job 2			280	62				280	62				252	56				303	67	
Organizing			5	1				14	3				19	4				14	3	
Unemployment			51	12				23	5				0	0				0	0	
Total			450	100				450	100				450	100				450	100	
Allocation of land (ha.)																				
Traditional	1.5			60		0			0		0.5			14		0			0	
Modern	1.0			40		2.5			100		3.0			86		2.5			100	
Total			2.5	100				2.5	100				3.5	100				2.5	100	
Use of agronomic inputs																				
Nitrogen (kg)		147			59		287			115		352			101		287			115
Phosphate (kg)		62			25		100			40		127			36		100			40
Plants (thousands)		109			44		150			60		195			56		150			60
Use of funds (pesos)																				
Private funds	450					450					450					450				
Credit from banks	405					1,555					1,530					1,155				
Total			855		342			1,605		642			1,980		565			1,605		642
Maize output (kg)		6,481			2,592		8,750			3,500		11,442			3,270		8,750			3,500
Net household income (pesos)																				
Net farm income	5,000			42	2,000	6,325			47	2,530	8,384			57	2,395	6,325			34	2,530
Labor earnings	7,000			58		7,000			53		6,296			43		10,910			58	
Investment in human capital	—					—				—						1,515			8	
Total			12,000	100				13,325	100				14,680	100				18,750	100	

Note: Blanks indicate not applicable.
[a] Average peasant's household.
[b] Complete information.
[c] Larger holdings.
[d] Better employment opportunities.

Table 5. Parcels in the Project Area with Adoption Levels of the Nitrogen, Phosphorus, and Plant Density Recommendations

Practice	Level of Adoption	All Farmers in Puebla Area		Farmers on Credit Lists	
		1971	1972	1971	1972
		%			
Nitrogen	High (> 80)	33.6	44.8	72.9	75.8
	Intermediate (51–80)	15.0	14.0	19.9	17.7
	Low (0–50)	51.4	41.2	7.2	6.5
Phosphorus	High (> 30)	44.4	44.3	82.3	76.6
	Intermediate (21–30)	6.1	9.1	5.0	9.7
	Low (0–20)	49.5	46.6	12.7	13.7
Plant density	High (> 40)	23.8	39.4	29.8	37.1
	Intermediate (30–40)	29.0	33.9	28.7	34.7
	Low (0–30)	47.2	26.7	41.5	28.2

Source: Centro Internactional de Mejoramiento de Maiz y Trigo.

Conclusions

Differences among peasants in the endowment of human capital, physical capital, and organizational power determine the differences in opportunity cost of human time, transaction costs, and behavior in the face of risky events. The particular combination of these differences determines the observed distribution of adoption rates among peasant households.

The structural condition of the peasant economy studied in this paper challenges the simplest view that labor-intensive technologies per se will rapidly increase agricultural production and improve the peasants' welfare. If the aim of a rural development policy is to increase agricultural production in the *minifundista* sector, the following steps are necessary. At the level of agronomic research, the generation of less risky technologies is required, e.g., adaptability of the new high yielding varieties to differences in environmental conditions, and development of improved varieties and practices for crop systems. At the level of design and implementation of modernization projects, the organizational component should have as much importance as the information (extension) component. The Puebla Project is a good example of the complementarity between organization and communication in diffusion processes. At the adoption level an adaptive strategy shall be offered. For example, one might begin with a package of land-saving and labor-using technologies, such as the green revolution, so as to generate an accumulation process within the household, and then introduce more capital-using technologies. When doing so, two complementary approaches can be followed: to promote the development and adoption of "intermediate technologies" that are not labor displacing and can be produced within the rural sector and to continue the process of community organizing by developing "intermediate organizations"—as, for example, in a few cases of the Puebla Project in which solidarity groups bought tractors that were then rented to individual households.

Economists can provide valuable assistance in the design and evaluation of these types of programs if their research is grounded on a model of political economy that takes into account the overall opportunity set of peasant households within each specific socioeconomic structure and a structural form model of the allocation of human time at the household level. This simple application of economics promises to be a necessary substitute for reduced-form representations and one-modal explanations of the adoption problem.

Further theoretical and empirical research will require an expansion of the model to study the complexities of crop production systems (e.g., corn-bean combination) including the seasonal and intrafamilial allocation of human time (women-men and adults-children). The development of a multistage model to investigate the changes over time of peasants' perception of risk, β, due to learning experiences as well as the changes in the subjective probability of disaster, α_1, as resource constraints change will also be required.

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A Stochastic Policy Simulation of the World Coffee Economy

R. Edwards and A. Parikh

The paper analyzes the structure of the world coffee market and suggests policies that stabilize the export earnings of coffee-exporting countries. The major cyclical characteristics of the coffee economy may be explained by a simultaneous equation model, which considers the lagged response of supply to price. The most successful policies include the development of rapidly maturing trees and the imposition of a quota on exports, both of which are effective in modifying the long-run cycle. A buffer stock policy is shown to be effective in eliminating short-run fluctuations, given sufficient resources.

Key words: buffer stock, fluctuations, quota, stochastic simulation, variance of export earnings, variation in maturation lag.

The aim of the paper is to analyze the structure of the world coffee economy and to suggest policies to minimize the fluctuations in export earnings of the coffee-exporting countries. An econometric model is outlined, and its predictive performance over the sample period is examined.

The coffee economy is simulated up to the year 2000, and various properties of the basic model are analyzed. Although the estimated equations are all subject to stochastic error, the simulations are carried out in both stochastic and nonstochastic frameworks, the latter treating all equations as if they were completely deterministic. Following the simulations of the basic model, policy instruments such as a buffer stock and a quota scheme are introduced in an attempt to evaluate their success in dealing with the various fluctuations.

The Model

A brief outline of some of the major characteristics of the coffee economy may assist in the understanding of the model. For coffee, there is a tendency for a year of high production to be followed by one of low production. Rourke indicates that the coffee tree suffers from the strain of a heavy harvest in such a way that it cannot carry as much fruit in the following year (p. 202). However, within large geographical areas it is likely that the various local districts will have their high and low production years more or less independently of each other. Consequently, it is only when small geographical areas are considered that the two-year pattern is likely to be pronounced. Various other factors influencing the size of the crop, including climatic factors, are considered in Rourke. Random fluctuations in coffee production, though not as violent as for many other primary products, are nevertheless quite substantial and may to an extent be due to the deliberate stock-holding policies of Brazil.

The low price elasticity of demand, along with the lagged response of supply to price, causes the long-run coffee cycle; small shortages lead to large price increases, inducing large scale expansion. After a maturation lag of about five years, this results in excess supply, leading to price decreases. The duration of these cycles appears to be about twenty years. The last cycle began with the upswing of the late 1940s, giving way to a downswing lasting from the mid-1950s until 1972. There are indications that this cycle has come to an end and that a new upswing is beginning. This, however, seems to have been hindered by technological and institutional developments. The introduction of rapidly maturing arabica trees and the countercyclical policies of curtailing new plantings during price booms,

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Table 1. Definitions of Variables

WEP_t	=	World Exportable Production (1,000 metric tons)
USS_t	=	Stocks in the United States (1,000 metric tons)
IUS_t	=	Imports into the United States (1,000 metric tons)
IE_t	=	European Imports (1,000 metric tons)
IRW_t	=	Imports into the Rest of the World (1,000 metric tons)
PW_t	=	World Price of Coffee (cents/lb. on New York Market)
S_t	=	World Stocks (1,000 metric tons)
WI_t	=	World Imports (1,000 metric tons)
D_t	=	Dummy for even years
PW_t^*	=	Expected Prices (approximated by the moving average $(PW_{t-3} + PW_{t-4} + PW_{t-5})/3$).
π	=	Stationary Price (regarded as the "normal" price by producers, see Parikh 1974).
τ	=	Gestation Lag between Planting and Harvesting
ΔPW_t	=	Change in World Price
ΔIRW_t	=	Change in Imports into the Rest of the World
ΔS_t	=	Change in World Stocks
SEE	=	Standard Error of Estimate

along with the promotion of rehabilitation schemes during depression periods, have gone some way toward stabilizing production to the desired level. Attempts have been made on an international level to restrict sales and maintain price levels, notably by "Cafe Mundial" and "Cafe Suaves Centrales." These attempts have had very little success, so little in fact that even while the schemes were in operation coffee exports were at near record levels.

It appears, then, that fluctuations (both short-term annual variations and long-run cycles) persist in the world coffee market that require both explanation and control. It is hoped that the model outlined below will go some way towards this end.

A full discussion of the basic model is given in Parikh (1974). Consequently, its detailed derivation is not presented here. The main variables are defined in table 1, and the model is presented in its estimated form.[1] The model contains a simultaneous equation block within which world imports and world price are jointly determined, which is estimated by full information maximum likelihood (FIML), the other equations being consistently estimated by ordinary least squares (OLS). The t-statistics are given in parentheses (in the case of the simultaneous block, the figures are asymptotic t-ratios).

$$(1)\quad WEP_t = \underset{(15.47)}{2823.51} + \underset{(6.15)}{0.25} \sum_{\theta=1-\tau}^{t-\tau} (PW_\theta^2 - \pi^2) - \underset{(3.56)}{1281070}(1/PW_{t-2}^2) - \underset{(4.66)}{575.98}D_t.$$

$$\tau = 5. \qquad R^2 = 0.858.$$
$$\pi^2 = 1758.54. \qquad DW = 2.23.$$

$$(2)\quad USS_t = \underset{(2.55)}{123.20} - \underset{(2.11)}{0.07}\, PW^*_t + \underset{(4.51)}{0.57}\, USS_{t-1}.$$
$$R^2 = 0.504. \quad h = 4.02.$$

The following four equations are estimated by FIML.

$$(3)\quad IUS_t = \underset{(14.78)}{1901.82} - \underset{(2.97)}{1.09}\, USS_t - \underset{(4.99)}{9.40}\, PW_t.$$
$$\text{SEE} = 4.39\%$$

$$(4)\quad IE_t = \underset{(6.75)}{128.46} + \underset{(58.26)}{0.98}\, IE_{t-1} - \underset{(2.82)}{1.35}\, PW_t.$$
$$\text{SEE} = 3.26\%$$

$$(5)\quad \Delta IRW_t = \underset{(2.79)}{8.54} - \underset{(1.20)}{0.66}\, \Delta PW_t.$$
$$\text{SEE} = 6.09\%$$

$$(6)\quad PW_t = \underset{(2.65)}{54.64} - \underset{(6.57)}{0.005}\, S_{t-1} - \underset{(4.39)}{0.01}(WEP_t - WI_t).$$
$$\text{SEE} = 13.45\%$$

$$(7)\quad WI_t \equiv IUS_t + IE_t + IRW_t.$$

[1] The models are at a highly aggregate level. There is one "world price" and a "world" exportable production. From a realistic point of view, it is obviously desirable to consider various sorts of coffee and their respective prices separately and to differentiate between geographical areas. This would, however, greatly increase the size and difficulties of the model, and data on all the necessary variables are not available. The data used in estimation cover the period 1950–72.

(8) $IRW_t \equiv IRW_{t-1} + \Delta IRW_t$.

(9) $\Delta S_t \equiv WEP_t - WI_t$.

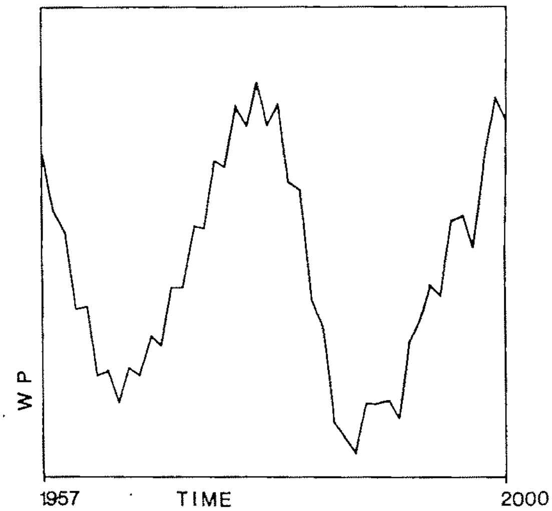
(10) $S_t \equiv S_{t-1} + \Delta S_t$.

An examination of the estimated relationships indicates that the explanatory variables account for 78% to 98% of the observed variation in the endogenous variables. The predictive performance over the sample period is satisfactory. There are, however, certain problems with the U.S. stocks equation, such as the obvious serial correlation (indicated by the Durbin h-statistic), but in view of the fact that it is purely a predictive relationship (servicing the U.S. imports equation) and the fact that data on these stocks are neither abundant nor very reliable, no correction procedure was carried out. Also, the coefficient of PW^*_t in this equation should a priori be positive but in fact turns out to be negative. A possible explanation lies in the quarterly data used in the estimation of this relationship. During periods of intensive roasting, existing inventory may be considerably drawn on. Although new purchases may be made to replenish the stocks, they need not be made in the same quarter. Similar results were obtained by Abaelu and Manderscheid.

Simulations of the Basic Model

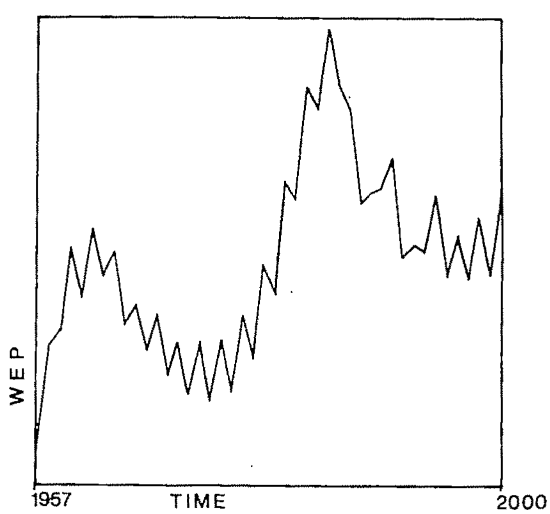
Several simulations of the model were carried out in order to determine its postsample period properties under varying conditions. The first simulation was nonstochastic, since some basis for comparison purposes was required. Following this, a normally distributed random element was introduced into each of the behavioral equations, with variances equal to the estimated sample variances of the error terms of the equations involved.[2] This enabled an assessment of the effect of the stochastic components on the cycles. The results of the stochastic simulations are based on the means and variances of the variables over twenty runs in order to eliminate spurious fluctuation.

Graphs of the important results are presented here. In these graphs, we are concerned with the shapes of the curves, which indicate the intensity of fluctuations. Consequently, although the scale is consistently preserved between graphs, the vertical axis does not indicate any numerical values.



Graph 1. World prices (nonstochastic simulation)

In the nonstochastic case, price displays a marked cycle of about twenty-years' duration (graph 1), the maximum of which is around sixty cents per pound, the minimum being about thirty cents per pound. There is little evidence of a trend. Exportable production also shows a cycle (graph 2) of about the same duration as that of the price variable, although out of phase with it by some seven to ten years. Here, the mean value displays an upward trend, as does the mean value of world imports. A similar cycle is exhibited by



Graph 2. World exportable production (nonstochastic simulation)

[2] This involves the assumption that the stochastic components have zero mean and finite variance over time and across equations. Also necessary is the assumption that error terms are normally and independently (of each other) distributed, with constant variance over time.

changes in stocks. An important feature is that excess supply (additions to stocks) is at a maximum when price is at a minimum, and vice versa. The mean value of excess supply is around zero, the generated series oscillating regularly between positive and negative, indicating that there is no tendency for stocks to diminish or accumulate over the simulation period.

A stochastic simulation of the model results in essentially the same pattern, except for minor residual fluctuations. There is also a tendency for the twenty-year cycles to be less violent than in the nonstochastic case. This particular result is consistent with the findings of Klein and Preston. There is a regular limit cycle of constant amplitude, the mean series of which is damped in a stochastic framework.[3]

Modifications of the Basic Model

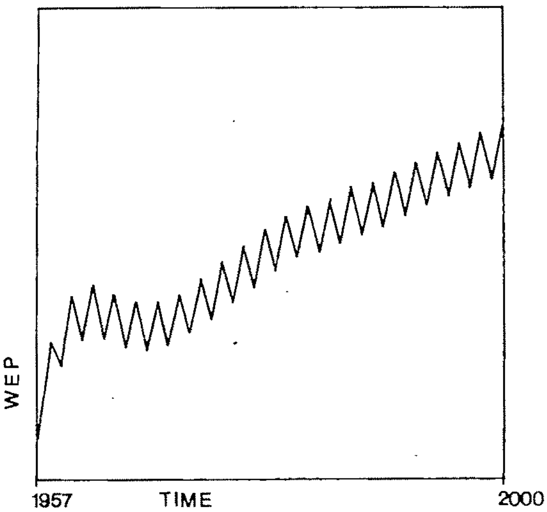
In order to obtain further information about the properties of the model and to determine the major causes of the long-run cycles, several modifications were made to the initial variant. First, the number of runs over which the means of the variables are calculated in the stochastic case was increased from twenty to one hundred in an attempt to determine the effect of sample size on the results. In fact, no noticeable difference is found. The cycles generated are of slightly smaller amplitude and display a tendency to be damped. The results, however, are almost identical to those of earlier stochastic simulations. Second, the period of simulation was extended to 250 years, to gain a better idea of the nature of the twenty-year cycle. The constant amplitude property was confirmed, indicating that the model belongs to a class of nonlinear models generating nondamped oscillations in a nonstochastic framework.

In order to test the hypothesis that one of the main causes of the long-run cycles is the response of world exportable production to price changes, it was decided to simulate the model with various changes in the price response coefficients in the exportable production equation (1), the estimated numerical values of which are 0.25 (long run) and −1281070 (short run) (see Parikh 1974). All combinations of these coefficients, plus or minus twice their respective estimated standard errors, were examined. With a high long-run and low short-run response, quite violent cycles resulted in all variables, displaying marked tendencies to be antidamped. With a strong short-run and weak long-run response, the pattern is reversed. Both price and exportable production display much gentler cycles than in the original case, with some tendency to be damped (although this conclusion is perhaps unjustified owing to the short simulation period). It would appear from this that if intervention, favorably affecting the response of production to price, were possible, then such a policy could break the cyclical behavior of the coffee economy, in principle.

A similar analysis was undertaken on the effect of changing the gestation period of coffee trees. As far as the model is concerned, this involves altering the value of τ in the exportable production equation (Parikh 1974). It is in fact known that the development of arabica trees that mature in three to five years has been a significant step towards the removal of the long-run cycle in arabica production. No such development, however, has taken place in the more fragmented Robusta production areas. Increased fertilizer usage and other technological advances have sometimes altered the natural foliage/bean cycle and could be responsible in part for the two-year price cycle. This is, however, far from conclusive (see Parikh 1971).

In the estimated model, a lag of five years between planting and first harvest was assumed. When this lag is increased to seven years, it is found that the long-run cycles become more pronounced, their duration increasing slightly. By reducing the gestation lag to two years, the model generates a heavily damped price cycle, rapidly converging to a more or less constant value of around forty-three cents per pound. A similar picture is presented by exportable production and changes in stocks. It is recognized that a two-year gestation period may be beyond the physiological limit with the current technology. However, the indication is that any reduction in the maturation lag will help to eradicate the long-run variations in production. Indeed, a lag of four years results in less violent cycles than the original case, although the tendency to be damped is not nearly so marked as in the two-year lag case (graph 3).

[3] If we were to predict the position of the system at a future time on the basis of the initial conditions, given a stochastic structure, we would not know which particular random realization to choose and would have to base the prediction on the expected value. It is the series of these expected values that we find to be damped.



Graph 3. World exportable production with two year maturation lag

Policy Simulations

Based on the original model, an examination was made of stabilization techniques designed to (*a*) modify the long-term cycle, and improve the trend in export earnings, and (*b*) reduce the amplitude of short-run fluctuations.[4] A priori, there is no single technique that could meet both objectives. However, the policy variables selected for consideration include intervention by a buffer agency (whereby direct attempts are made to stabilize prices), and a quota scheme (which attempts to impose artificial restrictions on the supply of coffee).

The welfare aspects of the stabilization of prices and earnings have been discussed by Massell. Possible criteria against which policies may be judged include their capacity to maximize expected earnings and to minimize fluctuations in those earnings.[5] Consequently, comparisons in this paper are made on the basis of the generated mean and variances of earnings over the simulation period.[6] This ideally involves the examination of the variation in earnings around a time trend, and in cases where this trend differs significantly between simulations, its effect was considered in the assessment.

Both of the policy variables require a "reference price" indicating some idea of the "desired" price level in each period. In practice, we use that range of prices determined by the reference price, plus and minus a constant. If the actual price lies within this range, no action is taken. Should, however, the actual price lie above the permissible ceiling or below the floor, there is a policy intervention, the magnitude of which is determined by the discrepancy between the actual and the ceiling or floor prices.

The reference prices used in the policy simulations are generated in two ways. The first involves taking a lagged moving average of the prices predicted by the model excluding the policy variable—rule A. This assumes that the authorities have access to the model and base decisions on it. The second method sets the reference price as a lagged moving average of the prices derived within the model including the policy variables and assumes that the authorities base decisions on past, observable price levels—rule B. In practice, after testing several alternatives, it was found that a two-year centered moving average of the most recent prices (both under rule A and rule B) was the most successful reference price from the point of view of the efficacy of both policies.[7]

Buffer Policy

In reality, the implementation of a buffer stock, which could adequately serve all major coffee-exporting countries, would involve complexities far beyond the scope of this study. In fact, such a policy is at present only within the financial and organizational range of a small number of arabica-producing nations and, as such, could only hope to affect a small section of the entire coffee economy. However, the incorporation of this sort of intervention into the present aggregate model will give some idea of its comparative success against other possible alternatives; perhaps not on an

[4] It must be assumed here that the structure of the model does not change with the introduction of the policy instruments. This may be particularly unrealistic with respect to the stocks equation, which may be significantly affected by the presence of a buffer agency. However, in the absence of the relevant data, it is not possible to reestimate the structure to take account of this.

[5] Earnings are defined as world imports multiplied by price, on the assumption that actual imports are equal to actual exports.

[6] The method most frequently used for the comparison of uncertain prospects has been this mean-variance approach. Rothschild and Stiglitz have attacked this approach and concluded that the results of such analysis may be spurious, only holding if the class of distribution is arbitrarily restricted. They suggest the use of a relative risk aversion parameter in a concave or convex welfare function. By evaluating the welfare gains in terms of expected earnings, an attitude of risk-neutrality is imposed, and in employing the variance minimization criterion, the assumption is implicitly made that the welfare function is such that an increase in variance (riskiness) is equivalent to a decrease in expected earnings.

[7] This is probably a consequence of the presence of the two-year product cycle.

institutional level but possibly on the grounds of logical feasibility.

A major problem in the simulation of this form of policy lies in the initialization procedure, involving decisions about the initial stock and fund of the agency and the specific form of intervention rule. Consequently, a large number of simulations were carried out for the purpose of determining the most successful initialization pattern.

It was initially decided to include some idea of a "desired level" of stocks into the intervention rule, in the hope that this would help stabilize prices, not only directly (through the "desired price" mechanism) but also through the effect of the level of stocks on prices. However, the stock term tended to dominate, and sometimes led to perverse results (e.g., when prices were too high, stocks were too low, and since the stock consideration was strong, the agency bought coffee to build up inventories, and the price was pushed up further). Consequently, this consideration was dropped, and the final form of the intervention rule was

$$BS_t = a(PR_t - PW_t), \tag{11}$$

where BS_t represents the change in the level of stocks held by the buffer agency in year t, and PR_t represents the ceiling or floor price. The size of the parameter a is not a real problem, since the process of adjustment is iterative, transactions continuing in any year t until the actual price converges on to a stable value. Consequently, the numerical value of a only affects the speed of adjustment in any one period. In fact, it was set equal to 14, since after trial and error this represented a reasonable compromise between excessive computer time and the possibility of nonconvergence.

The reference price range was initially set to

$$PR_t = \frac{(PW_{t-1} + 2PW_{t-2} + PW_{t-3})}{4} \pm 5 \text{ cents/lb.} \tag{12}$$

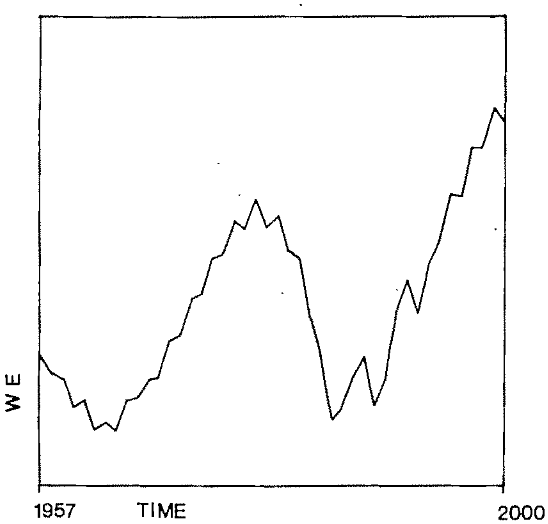
However, in an attempt to obtain an upward bias on the level of prices in order to improve earnings trends, it was decided to effectively narrow the permissible band in the downward direction, and the final form of the reference price range was Ceiling = Reference Price + 5 cents/lb. and Floor = Reference Price − 2.5 cents/lb.

The main problem in the initialization of the buffer stock (and indeed the problem that hindered its operation in later simulations) was the setting of the initial stock and fund of the agency. This was particularly crucial, since a constraint was built into the simulations, limiting the operation of the agency in accordance with its available resources. Thus, transactions involving the buffer agency could continue only so long as stocks or funds remained positive, where the buffer agency was required both to buy and sell at the current world price.

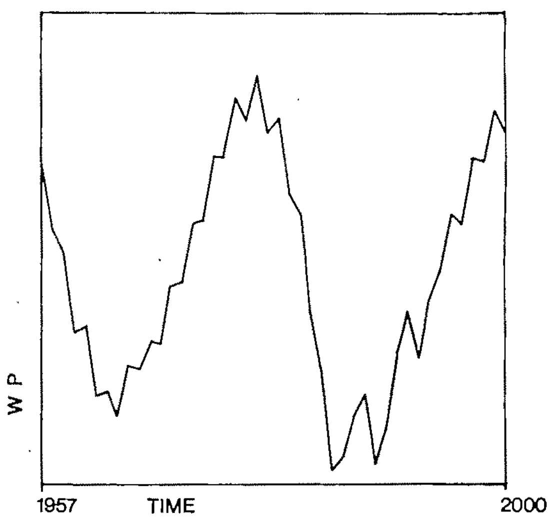
The first initial fund and stock figures considered were \$500,000 and 1,000 metric tons, respectively. In many ways, these are ridiculously low figures and indeed resulted in an almost completely ineffective agency. After a certain amount of trial and error, the final values were set to \$40 million of fund and 50,000 metric tons of stock. One of the main conclusions of this set of simulations was that to be really effective the buffer agency must operate on a very large scale. For cocoa, for instance, the Organization has accumulated funds of \$50 million and envisages a stock of about one-fifth of the entire world crop. The finance for this scale of operation has been a major cause of dispute in the International Coffee Agreement negotiations on this policy. Even with this higher level of resources, intervention by the simulated agency was often hampered by insufficient stock and finance.

This initialization procedure was, somewhat unrealistically, carried out exogenously (i.e., the fund and stock were assumed to be already available so that no initial purchases were required). Also, no storage capacity constraint was considered, although this would obviously limit the agency's actions to a very large degree. With this final set of initial conditions, there is an actual worsening of the cyclical behaviour of the economy under policy intervention. Under both rule A and rule B, the means of both prices and earnings fall, and there is an increase in their variances. There is evidence to suggest that the policy, especially under rule A, is successful in reducing short-run fluctuations (graph 4). This being the case, the increases in the variances can only be attributed to an actual aggravation by the policy of the long-run cycle.

Even when the policy is included in a stochastic simulation of the model, no improvement results. Although under rule A there is an increase in mean price from forty-two cents per pound to forty-seven cents per pound, its variance is almost doubled. Al-



Graph 4. **World earnings with buffer stock policy intervention (rule A)**



Graph 5. World prices with buffer stock policy intervention (rule A)

though the variance of earnings falls by 25%, there is a fall in its mean by about $17 million per year. There is also evidence to suggest that the twenty-year cycles have become antidamped (graph 5). The antidamped nature of the cycles is more pronounced under rule B, although short-run fluctuations are considerably reduced.[8] This is perhaps explicable in terms of the implicit difference equation describing price. Especially under rule B, where the reference price is determined by lagged values of the endogenous price variables, the roots of this equation may have been increased beyond unity by the inclusion of the policy and would account for the antidamped nature of the cycles.

The failure of the buffer agency to make any consistent reduction in the fluctuations in earnings may be explained in two ways. First, it involves an essentially short-term policy, which does not take long-run cycles into account in the determination of its reference prices or interventions. Second, the fluctuations in coffee export earnings may be caused primarily by the supply situation. Work done by the International Monetary Fund and the International Bank for Reconstruction and Development suggests that, if this is the case, then a buffer agency will have little success and a policy that attempts directly to stabilize supply will be of greater value. One such policy is the imposition of a quota on exports.

Quota Policy

Although the quota policy requires a similar reference price to the buffer policy, the initialization procedure is much simpler. First, an initial quota must be determined for each year. It was decided to set this equal to the trend value of world imports in an attempt to maintain a dynamic equilibrium between world supply and demand. Second, a mechanism must be developed by which adjustments to the initial quota may be made, according to prevailing price levels. The simplest such mechanism is

$$QA_t = QI_t + a(PR_t - PW_t),\ a < 0, \tag{13}$$

where QI_t is the initial quota, QA_t is the adjusted quota, and PR_t is the ceiling or floor of the reference price range (determined as in the case of the buffer stock policy). The value of a in this relationship was set to -24.[9]

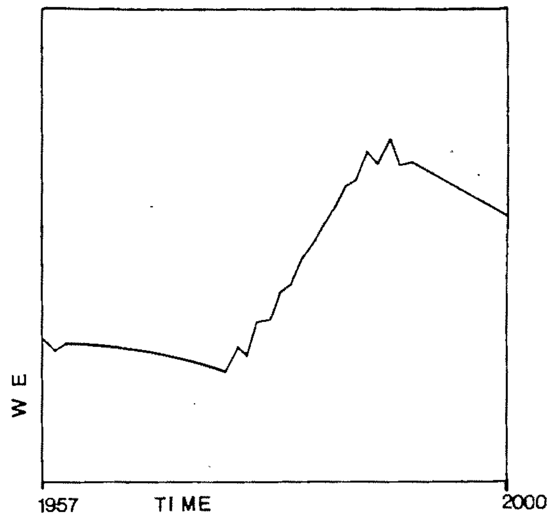
In order to take account of the fact that more than one quota adjustment is possible in any year, comparisons between the actual and

[8] All of the above simulations were carried out under the assumption that the buffer agency involves costless operation. In order to gain some idea of the costs involved, a separate simulation of the model was carried out. With a fixed cost of $2 million per annum, a variable cost of 5% of the value of stocks and a discount rate of 8%, the total discounted cost of the agency (ignoring initialization) was about $24 billion over the entire forty-four years of the simulation, indicating a very high cost relative to benefits. However, the particular figures considered may not reflect the situation facing an actual agency.

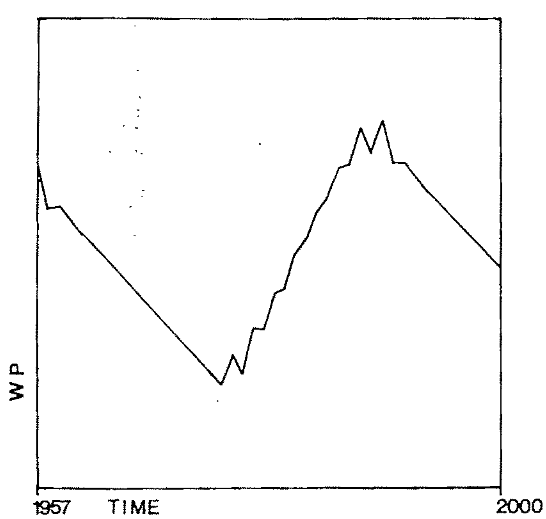
[9] In order to gain an idea of the response coefficient, the adjustment mechanism was estimated using data for the quota period (1964–72). Because of the low number of observations, the estimate of a cannot be taken as accurate, but it was felt that the general magnitude could be validly employed.

reference prices were made after every adjustment, and further modifications were made to the quota as necessary. This process continued until the price converged to a stable value, after which no further adjustments were made in that period. All simulations are carried out under the assumption that producers obey the quota restrictions on exports. This policy achieves a certain degree of success under rule A. In the nonstochastic framework, although mean earnings over the simulated period fall by about 2.5%, the variance is decreased by 20%. There is strong evidence to suggest that this fall in variance is almost entirely due to a reduction in the magnitude of short-run fluctuations, since there is no indication that the long-run cycle is significantly affected. A stochastic simulation results in a worse policy performance. Both the means of price and earnings fall, whereas their variances display increases. This appears to be caused by an increase in the amplitude of the long-run cycles, since the short-term fluctuations seem to have been eradicated. There is also a tendency for the cycles to be antidamped. The extremes on the first phase of the price cycle, for instance, are twenty-nine cents and fifty-seven cents per pound, whereas on the second phase they are twenty-three cents and fifty-nine cents per pound, respectively.

A nonstochastic simulation of the model under rule B, however, results in a much greater degree of success for the policy. Mean price increases by around 8% and mean earnings increase by 12%, while the variance of price falls by about 56%, that of earnings displaying a 21% decrease. This is to a large extent due to the total eradication of the short-run fluctuations over large ranges of the simulated period. It is also interesting that, although the amplitude of the long-run cycles does not appear to have been affected, their frequency is halved, so that each cycle has a duration of about forty years (graphs 6 and 7). These results are echoed in the stochastic simulation of this variant. The variances of price and earnings display 40% and 10% decreases respectively, while there are increases of 4% and 10% in their respective means. Again, the frequency of the long-run cycles is halved, while their amplitude falls slightly.



Graph 7. World earnings with quota policy intervention (rule B)



Graph 6. World prices with quota policy intervention (rule B)

Summary and Conclusions

The extent to which the simulated impact of the stabilization policies considered here reflects the actual capabilities of such instruments in the coffee economy obviously depends on the success of the model in capturing the underlying structure of the market. Many complexities have been ignored, and the simulations were carried out at a highly aggregate level. The somewhat unrealistic assumption is also made that the political and institutional factors necessary for the implementation of such policies are available. However, a crude comparison between various alternatives is possible within this framework, so that the

simulations have more than academic value. The main conclusions of the paper may be summarized as follows.

Coffee prices and production are characterized by strong long-term cycles, around which are found smaller short-run fluctuations. These may be explained to a large extent by a simultaneous-equations model, taking account of the lags in the responses of demand and supply to prices. Such a model was established to simulate the impact of alternative stabilization policies, the objectives of which were to improve the average level of earnings, to break the long-term cycle, and to reduce the amplitude of short-term fluctuations. The development of rapidly maturing varieties is the most natural and efficient way of breaking the long-term cycle. A reduction in the gestation lag from five to two years results in a complete cessation of the twenty-year pattern.

An international buffer stock policy can substantially reduce short-run fluctuations given the necessary resources, but may have an adverse effect on the long-term cycle. A quota policy is more successful, having few of the economic difficulties found in the buffer policy. However, owing to political considerations, it is probably much more difficult to enforce.

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Impact of Farm Size on the Bidding Potential for Agricultural Land

Duane G. Harris and Richard F. Nehring

A theoretical model is constructed to determine the maximum bid price that would be made for an acre of land by a decisionmaker with a given set of characteristics, capabilities, and expectations. The variables included that have an impact on the maximum bid price are net income, income variability, wealth, degree of risk aversion, marginal income tax rate, rate of pure time preference, and expected rate of growth in land income and prices. A numerical illustration of the model, developed for cash-grain farmers in Iowa, demonstrates the relative importance of the variables in determining bid-price differentials among farm-size classes.

Key words: farm size, land ownership, land value.

The size structure of farms, the control of farming, and the future of the family farm are issues that are all related to the ownership and control of a unique rural resource—land. The future complexion of the U.S. countryside is intimately tied to the ability of different economic groups to gain and maintain control of the land base. Continuation of past trends in farm enlargement and off-farm migration would vest the control of the farming community in fewer and larger operating units.

Krause and Kyle have outlined many of the incentives for further potential increases in the incidence of large farming units: production and marketing economies, management expertise, tax incentives, nonfarm investment, specialization, and conglomeration (pp. 752–55). Armstrong acknowledges these incentives, but also cites potential limits or impediments that may temper the continued trend toward larger units: managerial talent availability, problems of coordination and supervision, capital availability, labor availability, and risk and uncertainty.

While previous studies have identified some important aspects of the farm size and control issues, the extant literature provides no overall theoretical framework within which to incorporate these key incentives and diseconomies. The purpose of this paper is to develop a theoretical approach that can be used to determine the relationship between land ownership and the various characteristics of existing farm size classes. It is assumed that the future ownership of land will be determined by the relative bidding potential of participants in the land market.

A theoretical model of maximum bid price is developed and discussed in the next two sections. Then an application of the model is made to cash-grain farms in Iowa. Finally, a summary and some conclusions of the study are offered.

Theoretical Model

The basis for the development of a theoretical model of bidding potential is provided by Pratt. In his formulation of a measure of the degree of risk aversion, he defines the bid price as the largest amount a decisionmaker would willingly pay to obtain a risky asset (p. 124). This bid price is given by the equation

$$(1) \qquad u(x) = E\{u(x + z - B)\},$$

where x represents the level of assets held by the decisionmaker; u, his utility function; E, the expected value operator; z, the risky asset;

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and B, the bid price.[1] In this analysis, x will be interpreted as the level of net worth of the decisionmaker and z as a random variable denoting the value of an acre of land. The term B then represents the maximum price a decisionmaker would be willing to pay for that acre.

By using a Taylor expansion to expand u around x (Yamane, pp. 280–81), an approximation for the bid price can be derived from the quadratic equation

$$(2)\quad \tfrac{1}{2}\, u''(x)B^2 - [E(z)u''(x) + u'(x)]B + \tfrac{1}{2}\, \{\sigma_z^2 + [E(z)]^2\}\, u''(x) + E(z)u'(x) = 0,$$

where $u'(x)$ and $u''(x)$ are the first and second derivatives of the utility function, and $E(z)$ and σ_z^2 are, respectively, the expected value and variance of the value of an acre of land.

By utilizing Pratt's measure of local risk aversion (p. 125)

$$(3)\qquad r(x) = -\frac{u''(x)}{u'(x)},$$

equation (2) can be rewritten as

$$(4)\quad \tfrac{1}{2}\, r(x)B^2 - [r(x)E(z) - 1]B + \tfrac{1}{2}\, r(x)\{\sigma_z^2 + [E(z)]^2\} - E(z) = 0.$$

Solution of this quadratic equation gives B in terms of $r(x)$, $E(z)$, and σ_z^2:

$$(5)\quad B = E(z) - \frac{1}{r(x)} \pm \left\{\frac{1}{[r(x)]^2} - \sigma_z^2\right\}^{1/2} \quad \text{for } r(x) \neq 0,$$

and

$$B = E(z) \text{ for } r(x) = 0.$$

If, however, z is defined as the discounted value of future income from an acre of land and is derived from a standard perpetuity model incorporating a constant rate of growth (e.g., Van Horne, pp. 21–22), the value of an acre of land can be defined as

$$(6)\qquad z = \frac{y\,(1-t)}{(i-g)},$$

where y represents a random before-tax income stream, t is the marginal income tax rate of the decisionmaker, g is the expected rate of growth of after-tax income, and i is the decisionmaker's discount rate for pure time preference. Then $E(z)$ and σ_z^2, respectively, become

$$(7)\qquad E(z) = \frac{(1-t)}{(i-g)}E(y)$$

and

$$(8)\qquad \sigma_z^2 = \left[\frac{(1-t)}{(i-g)}\right]^2 \sigma_y^2.$$

Substituting equations (7) and (8) into equation (5) gives

$$(9)\quad B = \frac{(1-t)}{(i-g)}E(y) - \frac{1}{r(x)} \pm \left\{\frac{1}{[r(x)]^2} - \left[\frac{(1-t)}{(i-g)}\right]^2 \sigma_y^2\right\}^{1/2} \quad \text{for } r(x) \neq 0,$$

and

$$B = \frac{(1-t)}{(i-g)}E(y) \text{ for } r(x) = 0.$$

The maximum bid price B is defined in terms of the parameters of the utility function (through the measure of the degree of risk aversion, r(x)), which are the expected value and variance of income, $E(y)$ and σ_y^2; the expected rate of growth of income, g; the marginal tax rate of the decisionmaker, t; and the decisionmaker's rate of pure time preference, i. Specification of the values of these parameters and variables allows the calculation of the bid price for any potential purchaser of farmland.

Decisionmaker Characteristics and the Maximum Bid Price

The values of the parameters and variables in the bid-price equation (9) are related to the characteristics, capabilities, and expectations of the decisionmaker. An evaluation of the influence of these parameters and variables on the maximum bid price for an acre of land can be carried out by taking the partial derivatives of B with respect to $E(y)$, σ_y^2, $r(x)$, x, t, i, and g.[2] Thus,

$$(10)\qquad \frac{\partial B}{\partial E(y)} = \frac{(1-t)}{(i-g)} > 0,$$

and

$$(11)\qquad \frac{\partial B}{\partial \sigma_y^2} = -\frac{(1-t)^2}{2D(i-g)^2} < 0,$$

[1] The variables B and z are equivalent to π_b and $\tilde{z}$ in Pratt's notation.

[2] Since the bid price is defined as the largest amount a decision maker will pay for a risky asset, the solution value for B in equations (5) and (9) requires selection of the positive square root. Selection of the positive square root in turn establishes the sign of $\partial B/\partial\sigma_y^2$ in equation (11) to be negative. Finally, it can be demonstrated that requiring the solution value of B to be real causes the sign of $\partial B/\partial r(x)$ in equation (12) to be negative.

where

$$D = \left\{\frac{1}{[r(x)]^2} - \left[\frac{(1-t)}{(i-g)}\right]^2 \sigma_y^2\right\}^{1/2},$$

$$(12) \quad \frac{\partial B}{\partial r(x)} = \frac{1}{[r(x)]^2}\left\{1 - \frac{1}{Dr(x)}\right\} < 0,$$

and

$$(13) \quad \frac{\partial B}{\partial x} = \frac{r'(x)}{[r(x)]^2}\left\{1 - \frac{1}{Dr(x)}\right\} \gtreqless 0.$$

The sign of $\partial B/\partial x$ depends upon whether the decisionmaker exhibits an increasing, unchanged, or decreasing degree of risk aversion over wealth, as determined by the sign of $r'(x)$.

$$(14) \quad \frac{\partial B}{\partial t} = -\left[\frac{E(y)}{(i-g)} - \frac{(1-t)\sigma_y^2}{D(i-g)^2}\right] \gtreqless 0.$$

The sign of $\partial B/\partial t$ is ambiguous because a change in the marginal tax rate influences the bid price in two ways. An increase in the marginal tax rate will decrease the bid price through a reduction in expected after-tax income from an acre of land, but increase the bid price through a reduction in the variability of after-tax income:

$$(15) \quad \frac{\partial B}{\partial i} = -\frac{(1-t)}{(i-g)}\left[\frac{E(y)}{(i-g)} - \frac{(1-t)\sigma_y^2}{D(i-g)^2}\right] \gtreqless 0,$$

and

$$(16) \quad \frac{\partial B}{\partial g} = \frac{(1-t)}{(i-g)}\left[\frac{E(y)}{(i-g)} - \frac{(1-t)\sigma_y^2}{D(i-g)^2}\right] \gtreqless 0.$$

The signs of $\partial B/\partial i$ and $\partial B/\partial g$ likewise are ambiguous without knowledge of the sizes of the parameters in the model. The effect of i and g on the bid price, however, will be of equal magnitude but opposite sign.

Interpretation of equations (10) through (16) leads to the following general results:

(*a*) A *ceteris paribus* increase in expected before-tax income resulting from economies of scale in production or marketing, more efficient management, specialization, or conglomeration will result in a higher maximum bid price per acre.

(*b*) A *ceteris paribus* increase in the variability of before-tax income resulting from greater degrees of operating or financial leverage or from additional exogenous uncertainty will result in a lower maximum bid price.

(*c*) A *ceteris paribus* increase in the degree of risk aversion resulting from changes in the parameters of the utility function will lead to a reduction in the maximum bid price.

(*d*) A *ceteris paribus* increase in the initial wealth position of the decisionmaker will result in a higher maximum bid price if the decisionmaker is decreasingly risk averse over wealth ($r'(x) < 0$). If the decisionmaker is increasingly risk averse ($r'(x) > 0$), an increase in the initial wealth position will result in a lower maximum bid price. If the decisionmaker's degree of risk aversion remains unchanged over wealth ($r'(x) = 0$), the bid price will be unaffected by an increase in the initial wealth position.

(*e*) A *ceteris paribus* increase in the marginal tax rate will, under reasonable assumptions about the sizes of the parameters in the model, lead to a reduction in the maximum bid price.

(*f*) A *ceteris paribus* increase in the decisionmaker's rate of pure time preference will, under reasonable assumptions about the sizes of the parameters in the model, lead to a reduction in the maximum bid price.

(*g*) A *ceteris paribus* increase in the decisionmaker's expected rate of growth of after-tax income will, under reasonable assumptions about the sizes of the parameters in the model, lead to an increase in the maximum bid price.

These conditions also can be interpreted in the specific context of potential future ownership of farmland. If it can be assumed that prospective buyers in the land market are decreasingly risk averse over wealth, land will be acquired by those bidders with (*a*) the highest expected before-tax income per acre (*b*) the lowest variability of before-tax income, (*c*) the largest initial wealth position, (*d*) the lowest degree of risk aversion, (*e*) the lowest marginal income tax rate, (*f*) the lowest rate of pure time preference, and (*g*) the highest expected rate of growth of after-tax income.

It is likely, however, that no bidder will

Table 1. 1969 Summary Characteristics of Iowa Cash-grain Farms and Farmers

Farm Class	0	I	II	III	IV
Average farm size (acres)	1,307	630	390	254	170
Net income per acre ($E(y)$)	\$36.18	\$39.16	\$33.95	\$26.67	\$19.04
Variability of net income (σ_y)	\$6.80	\$7.36	\$6.62	\$5.05	\$6.33
Marginal tax rate (t)	43%	32%	28%	25%	24%
Discount rate (i)	0.09082	0.09082	0.09082	0.09082	0.09082
Expected growth rate (g)	0.04387	0.04387	0.04387	0.04387	0.04387
Net worth (x)	\$234,167	\$117,489	\$99,953	\$98,568	\$47,616
Measure of risk aversion ($r(x)$)	0.00298	0.00594	0.00699	0.00709	0.01467
Per-acre bid price (B)	\$429	\$533	\$485	\$403	\$231

have an absolute advantage in all these categories. For example, decisionmakers with the highest expected income per acre may also be in the highest tax bracket. The ultimate winners in the land bidding process can be identified only with numerical specification of the parameters and variables in equation (9). The next section presents a numerical application of the model to cash-grain acreage in Iowa.

Farm Size and Bidding Potential for Cash-Grain Acreage

To demonstrate the applicability of the theoretical model to the issues of land ownership and control, maximum bid prices were estimated for various size categories of cash-grain farms in Iowa.[3] The size categories used were classes 0 to IV farms from the 1969 Census of Agriculture. For each of the classes, the Census indicates the total acreage, number of farms, and average size of farm. In 1969, for example, the average size of cash-grain farms in Iowa ranged from more than 1,300 acres for farms in class 0 to 170 acres for farms in class IV (table 1).

Data

Various sources of data were used in an attempt to define the characteristics of the average cash-grain farmer in each size category. Estimates were necessary for $E(y)$, σ_y, t, i, g, x, and $r(x)$ for each size classification.

The expected before-tax income per acre for 1970, $E(y)$, was based on the 1969 average as derived from Census data. Expected before-tax net income attributable to ownership of an acre of land was estimated by summing the market value of all agricultural products sold and receipts from government farm programs, subtracting total farm production expenses, and dividing the result by the total number of acres in cash-grain farms (table 2). Net income figures ranged from \$39.16 per acre for class I farms down to \$19.04 per acre for class IV farms (table 1). Economies of size resulted in increasing returns to size over classes IV to I. Moving from the average class I size farm to the average class 0 size, however, brought a reduction in net income per acre.

Variability of before-tax income per acre for each size class was estimated by using 1965–69 time-series data obtained from Iowa Farm Business Association records. The coefficient of variation was estimated for each size class in the Farm Business record survey and applied to the average net income figure for the appropriate size class in the Census scheme to give an estimate of the standard deviation of income, σ_y (table 1).

Taxable income per farm was estimated to determine the appropriate marginal tax rate for each size category. Total net income, as derived earlier, was divided by number of farms to get net income per farm for each size category (table 2). According to a study by Evenson, for Iowa farms during 1969 and 1970, taxable farm profits as reported by the Internal Revenue Service represented about 46% of net farm income as reported by the U.S. Department of Agriculture. Application of the 46% adjustment to net income per farm gave per-farm taxable income from farming for each size category (table 2).

Off-farm income for each class size was obtained from the Survey of Agricultural Finance—1970. This income includes reported receipts from all off-farm activities or sources of income, excluding government payments. Off-farm income per farm was added to taxable income from farming to get

[3] Cash-grain farms were used to avoid the complications of estimating income from livestock facilities that would accompany land in diversified farming areas.

Table 3. Class Size Characteristics and Bid-Price Differentials

Class Comparisons	Bid Price of First Class	Source and Size of Bid-Price Differentials: Net Worth	Marginal Tax Rate	Before-Tax Net Income	Net Income Variability
0–I	$429.08	$−10.09	$ 76.19	$ 43.16	$−4.96
0–II		−13.65	101.41	−34.20	1.99
0–III		−13.98	121.05	−151.92	18.75
0–IV		−39.84	107.50	−277.45	11.87
I–II	533.40	−5.93	28.55	−79.90	8.51
I–III		−6.49	49.67	−199.52	25.92
I–IV		−49.61	45.94	−325.69	27.13
II–III	484.63	−0.51	18.59	−116.29	16.56
II–IV		−39.61	20.28	−241.35	7.22
III–IV	402.98	−24.68	4.40	−123.51	−28.02
IV	231.17				

the classes rank from highest to lowest as I, II, 0, III, IV. The surprising result is that the largest class size, class 0, falls in the middle of the bidding-potential range.

To try to isolate the relative importance of the class size characteristics on the bid-price differentials between classes, bid prices were calculated by using incremental changes in characteristics. Results are shown in table 3. For example, line 1 of table 3 compares classes 0 and I. Column 1 gives the bid-price as $429.08 per acre for a decisionmaker with all class 0 characteristics. Column 2 shows that the bid price would decline $10.09 to $418.99 if the decisionmaker had all class 0 characteristics but had the net worth of a class I decision maker. Column 3 shows that the bid price would increase $76.19 to $495.18 ($429.08 − $10.09 + $76.19) if a decisionmaker with class 0 characteristics and class I net worth also had a class I marginal tax rate. Summing across line 1 for the 0 to I classes gives the class I bid price of $533.40.

Interpretation of the information in table 3 offers some general insights. If all decisionmakers have the same utility function, rate of pure time preference, and expected growth rate, and if the parameters and values used in the model are indeed representative of the characteristics of the various size classes, then the major sources of bid-price differentials are differences in before-tax income per acre and differences in marginal tax rates. Differences in net worth position and income variability, however, also have some influence.

Finally, the importance of size and the degree of risk aversion can be assessed by comparing the calculated bid prices with those that would pertain to a risk-neutral decisionmaker. If the decisionmaker is risk neutral, $r(x) = 0$, and the maximum bid price is that given by equation (9). Comparisons of calculated bid prices using the utility function given in equation (17) with those using any risk-neutral utility function are given in table 4. The difference between the bid prices represents the risk premium required by the decisionmaker. In general, the size of the risk premium increased as the farm size declined.[10] The bid prices for risk-neutral classes III and IV farmers are less than those for risk-averse classes 0, I, and II farmers.

Summary and Conclusions

The trend of the last two decades to larger and larger farming units has been viewed by many as a threat to the family farm. Disagreement exists as to whether that trend will continue. The analysis in this paper was based on the assumption that the future control of farming will be vested in those farmers with the greatest bidding potential for agricultural land. A

Census was $434 per acre. In an auction system, the market price will not be equal to the maximum bid price. Theoretically, it should be one bid unit higher than the second highest maximum bid price of the participants in the auction. The difference between the maximum bid price of the purchaser and the actual purchase price represents a form of consumer surplus that accrues to the purchaser.

[10] The notable exception is class III, where the risk premium declined. Derivation of the risk premium gives $\pi = 1/2\, r[x + E(z)]\, \sigma_z^2$ (Pratt, p. 125), where π is the size of the risk premium. Thus, the risk premium is a function of initial net wealth, the expected value of an acre of land and the variability of the value of an acre of land. The risk premium also can be defined as $\pi = \frac{r[x + E(z)](1 - t)^2}{2(i - g)^2}\sigma_y^2$. For class III farms, the variance of income σ_y^2 was substantially smaller than for the other categories. Hence, the smaller risk premium than for adjacent size classes.

Table 4. Required Risk Premiums per Acre

Farm Class	0	I	II	III	IV
Risk-averse bid price	$429.08	$533.40	$484.63	$402.98	$231.17
Risk-neutral bid price	439.25	567.17	520.64	426.04	308.21
Risk premium	10.17	33.77	36.01	23.06	77.04

theoretical model was developed to explore some of the important variables affecting that bidding potential, and a numerical example of the model was developed for cash-grain farms in Iowa.

The theoretical model was constructed to determine the maximum bid-price that would be made for an acre of land by a decisionmaker with a given set of characteristics, capabilities, and expectations. The variables included that have an impact on the maximum bid price are (*a*) before-tax net income per acre, (*b*) variability of income per acre, (*c*) initial net wealth position, (*d*) degree of risk aversion, (*e*) marginal income tax rate, (*f*) rate of pure time preference, and (*g*) expected rate of growth in land income and prices. As such, the model is capable of incorporating most arguments that are typically advanced for or against the continued growth of farming units.

The numerical example identified and estimated the average characteristics of Iowa cash-grain farmers in each of the Census farm size classes 0 to IV for the year 1969. These characteristics were inserted into the model to determine the maximum 1969 bid price by the average farmer in each class. Estimated bid prices ranged from a high of $533 per acre for class I to a low of $231 per acre for class IV.

Although the results of the numerical example must be interpreted with caution, they do provide some insight. First, it seems that the largest farms may not have the greatest bidding advantage after all. A combination of higher marginal tax rate and diseconomies of size may cause class 0 farmers to have a lower maximum bid price than either class I or class II farmers. Or, interpreted differently, if class 0 farmers are to consistently outbid smaller farmers, they must have a lower degree of risk aversion, a lower required rate of return on investment, or a higher expected growth rate for income and land prices than smaller farmers. If all farmers have the same utility function, the same required rate of return, and the same expected growth rate (as we have assumed in the model), it seems that the greatest threat to the small family farm is the larger family farm.

The results of this study are consistent with the conclusions of Krause and Kyle regarding the importance of economies of size and tax incentives in the growth of farming units. In addition, however, the results indicate that wealth position, income variability, and the degree of risk aversion are important considerations for the issues of the ownership and control of farmland. If public policy is intended to "save the family farm," it may be necessary to devise schemes to deal with all these factors.

Small farmers may be at a particular disadvantage in their attempt to bid away land from their larger neighbors. For example, even if classes III and IV farmers are risk neutral, the results of the study imply that they may have lower maximum bid prices than risk-averse classes 0, I, and II farmers. Thus, policies designed to shift the burden of risk away from small farmers, in and of themselves, may be inadequate to make those farmers competitive in the land market.

The analysis in this study points out the potential for additional work at both the theoretical and empirical level. While the theoretical model represents a start in formulating the bidding potential of investors in farmland, much work is yet to be done. Since domestic and alien nonfarm investors are important potential participants in the land market, and since some farmers may have substantial off-farm investments, it would be especially fruitful to extend the model to capture the impact of diversification on bidding potential. Also, the model could be adapted specifically to investigate the influence of public policy variables such as acreage restrictions, differential property tax rates, and differential income tax rates.

The attempt to generate meaningful estimates of decisionmaker characteristics, capabilities, and expectations painfully demonstrates the need for additional data. One must be especially uneasy with the shortcomings of some of the data used in the numerical illustration. The necessity to use aggregate census data for generation of income estimates, to use a different source for income

variability, to assume the proportion of taxable income to net farm income is the same for all farm-size classes, and to assume that all classes of farmers have the same utility function leaves the researcher most anxious for new and better data sources.

In a resource-scarce environment, it is necessary to establish priorities on data gathering efforts. The preliminary results of the numerical illustration suggest that better measurements of net income and effective marginal tax rates across investor classes are of primary importance. An evaluation of the impact of degree of risk aversion on bidding potential suggests that measurement of investors' utility functions is also a priority item for this and other research. Hopefully, this study offers some encouraging incentives for researchers in those areas. The issues of ownership and control cannot be completely resolved until more accurate and complete specifications of the important parameters are made.

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Landowner Benefits from Use-Value Assessment under the California Land Conservation Act

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The factors that determine the size of benefits to landowners who participate in the use-value assessment program under the California Land Conservation Act are identified, and the level of benefits available to landowners is calculated for several cropping patterns in Sacramento County. Possibilities for decisionmakers to increase participation by altering benefits is examined through a sensitivity analysis on the factors that determine benefit levels. It is concluded that little opportunity exists for decisionmakers to influence enrollment significantly except through measures that influence land values or development expectations of landowners.

Key words: agricultural land preservation, land use, preferential taxation, property taxes, use-value assessment.

Use-value assessment programs, whereby land is taxed at its agricultural rather than market value, provide property tax relief to landowners in at least thirty five states (Gloudemans). In some states, e.g., California, such programs are explicitly directed at reducing the rate of conversion of agricultural lands to urban uses (Henke, California Legislature). The use-value assessment legislation that is embodied in the California Land Conservation Act (CLCA)[1] has three major objectives: to reduce undesirable sprawl resulting from the "premature and unnecessary conversion of agricultural land to urban uses," to maintain lands in agricultural use for their open-space value, and to preserve agricultural land in production to assure an adequate food supply and healthy agricultural economy (*California Government Code,* Sec. 51220).[2]

To obtain benefits under the CLCA, a contract is required between the landowner and the county or city, by which the land is maintained in agricultural or open-space use for a specified minimum period. Once a contract is in effect, it may be terminated either by nonrenewal or by cancellation. With a ten-year contract, notice of nonrenewal may be given at any time after the end of the first year. The contract then continues for nine more years (the runout period) with assessments rising to full market value by the termination date. Lacking notice of nonrenewal, another year is added to the contract term each year, so that it continues to maintain the use restriction for ten more years. Under special circumstances, which are judged to be in "the best public interest," a contract can be cancelled immediately and thus not be subject to the runout period.[3]

To significantly reduce the rate of land conversion through contract enrollment, benefits of reduced property taxation accruing to landowners must be large enough to induce holding of the land in agriculture longer than if market value taxation were used. The size of the present value of future use-value taxation benefits depends on a number of important

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[1] The California Land Conservation Act of 1965 is widely known as the Williamson Act.

[2] Possible areas of conflict between these expressed goals have been discussed elsewhere (e.g., see Stanford Environmental Law Society). For purposes of this study, it is assumed that the intent was not to prevent all conversion of agricultural land to urban use but rather to discourage sprawled development of a leapfrog nature.

[3] Our analysis assumes that contract terminations are by nonrenewal. Specific requirements for contract cancellation are stated in *California Government Code*, Sec. 51282. A detailed discussion of the provisions and implementation of the Act may be found in Wagenseil.

parameters in addition to the difference between market and use value of the land. In this paper, six additional factors that determine the level of benefits are examined: future agricultural income, length of the contract period, property tax rate, discount rate of the landowner, discount rate in the runout formula,[4] and the reassessment time lag, i.e., the number of years elapsing between county reassessments.

This paper examines the impact of selected factors on benefit levels and thus the incentives to farmland owners to sign contracts under the CLCA. Some of the parameters that are examined can be altered by policymakers, while others are determined by the broader economic milieu. Although it is difficult to determine accurately the elasticity of contract enrollment to increased contract benefits, the results of the study provide some basis for policymakers, who are trying to influence enrollment by altering benefits, to select from among parameters under their control. The impact of exogenous factors (assuming lack of compensating actions by policymakers) is also examined.

Using data from a detailed parcel analysis of Sacramento County, the present value of the stream of reduced taxes is calculated as the measure of the incentive for the landowner to accept a contract. The effect of variations in the parameter values on the present value of contract benefits is explored to determine the sensitivity of benefits to parameter variations.

Calculation of CLCA Enrollment Benefits

Current Annual Tax Reductions

Three areas of Sacramento County were chosen for analysis based on their proximity to urban development and their diversity of agricultural activities. Market-value assessments were obtained from the county assessor's office for all parcels over twenty acres, and use-value assessments (CLCA assessed values) were obtained for the 113 parcels actually under contract. For the 678 noncontracted parcels, the use-value assessment was calculated by the capitalization of rental income method used by assessors throughout the state. The tax reduction was determined by multiplying the parcel tax rate by the difference between market and restricted-use assessed values.[5]

Present Value of Total Contract Benefits

The present value of contract benefits is calculated from estimated future annual tax reductions, which are based on current values of market and use-value assessments and an assumed land price pattern. The annual benefit, net of federal and state income tax payments, is calculated from

$$(1)\quad B_i = (AVM_i - AVR_i)\,(PTR_i)\,(1 - ITR),$$

where B_i = property tax benefit per acre in year i, AVM_i = estimated market assessed value in year i without a CLCA contract, AVR_i = estimated assessed value under CLCA contract in year i, PTR_i = estimated property tax rate in year i, and ITR = combined federal and state income tax rate.

For purposes of this study, a combined federal and state income tax rate of 40% is assumed. The assessment process is simulated by assuming a time lag between reassessments, during which time the assessed market value of the land is assumed to remain constant. The assessed value of land under contract (AVR) is estimated for each year from the initial CLCA-assessed values and from assumptions about changes in agricultural income. AVR is equal to the agricultural assessed value of the land ($AVAG$) until a notice of nonrenewal is given, at which time AVR is calculated from equation (2), which is specified in *California Revenue and Taxation Code*, Section 426(b):

$$(2)\quad AVR_i = AVAG_i + (AVM_i - AVAG_i)\,\frac{1}{(1 + r_s)^{T-i}},$$

where $AVAG_i$ = agricultural assessed value in year i, calculated by the capitalization of income method, r_s = the discount rate established by the state for use in the runout calculation (revised each year according to long-term bond rates), T = total number of years in contract period, and $T-i$ = number of years until contract expiration.

[4] The discount rate in the runout formula is set by the state each year according to long-term bond rates.

[5] The restricted-use assessed value is the assessment under CLCA contract and is determined from the agricultural rental value of the land, except during the runout period when it is determined according to equation (2).

Table 1. Initial Values Used in Sensitivity Analysis

	Rice	Dry pasture	Irrigated crops
Market assessed value/acre[a]	$254.25	$89.68	$188.67
Agricultural (CLCA) assessed value/acre[b]	91.41	17.55	96.04
Agricultural income/acre/year[c]	36.00	7.00	38.40
Property tax rate[c]	13.60	12.70	11.90

Source: California, Sacramento County.
[a] Average assessed values for noncontracted parcels.
[b] Estimated values based on cropping pattern and CLCA capitalization of income formula.
[c] Average values for each cropping pattern.

Analysis of Results

To examine the variation of program benefits to the landowner, a set of initial values for market and agricultural (CLCA) assessed value of the land, agricultural income, and property tax rate was defined for each cropping activity (see table 1). Cropping activities selected included rice, dry pasture, and the combined category of irrigated pasture and row crops (hereafter called "irrigated crops" for brevity). Initial values were based on actual data from the County Assessor's Office for noncontracted land. A set of baseline conditions was then specified for the seven parameters that determine the level of contract benefits. The baseline conditions and the variations of the parameters employed in this study are presented in table 2. The present value of benefits was calculated for the baseline conditions and for each change from the baseline condition, thereby providing an indication of the relative importance of the selected parameters and parameter combinations.

Current Annual Benefits

The estimated annual tax benefits for contracted lands and the potential benefits that could be obtained by enrollment of parcels not now under contract are summarized in table 3 according to cropping pattern. It is seen that the percentage reduction in the tax bill is sizable, ranging from 49% for irrigated crops to 80% for dry pasture for the noncontracted lands, and from 40% for irrigated crops to 72% for dry pasture for contracted lands. For dry pasture, the annual benefits of $5.76 for contracted land and $9.15 for noncontracted land exceed the rental value of $4 to $5 per acre, an indication of the large relative benefits that are attainable under the Act.

The larger percentage reductions available for noncontracted lands for all crops studied are due to the higher market values of noncontracted lands. Market values of noncontracted lands exceed those of contracted lands by between 18.8% (for irrigated crops) to 35.8% (for dry pasture). One possible explanation is that the noncontracted parcels contain a larger "urban increment" in their price and that owners did not enroll despite potentially larger

Table 2. Baseline Parameter Values and Variations Used in Sensitivity Calculations of CLCA Benefits

Parameter	Baseline	Variations from baseline
Market assessed value of land	6 %/year increase	3 %/year increase 10 %/year increase
Future agricultural income	initial values[a]	6 %/year increase 50 % initial increase
Contract length	20 years	10 years 30 years
Property tax rate	initial values[a]	1 %/year increase 3 %/year increase
Landowner's discount rate	8 %	6 % 10 %
Run-out formula discount rate	6.75%	5.75% 7.75%
Reassessment lag	3 years	1 year 2 years 4 years

Note: These baseline parameters and the variations were applied to all crops.
[a] See table 1.

Table 3. Assessed Values and Annual Tax Reductions Obtainable from a CLCA Contract

	Acres	Market assessed value[a] ($/acre)	Agricultural assessed value ($/acre)	Actual or potential annual tax reduction[b] ($/acre)	(%)
Rice					
Contracted parcels	826	213.34	95.87	15.84	55.1
Noncontracted parcels	8,026	254.25	91.41	22.19	64.0
Dry pasture					
Contracted parcels	21,709	65.98	19.00	5.76	72.2
Noncontracted parcels	25,731	89.68	17.55	9.15	80.4
Irrigated crops					
Contracted parcels	4,376	158.91	95.79	7.40	39.7
Noncontracted parcels	27,647	188.67	96.04	11.04	49.1

Source: California, Sacramento County.
[a] All land is assessed at 25% of appraised value in California.
[b] Actual reduction for contracted parcels; potential reduction for noncontracted parcels if placed under contract.

benefits because of the greater developmental potential of their land. Low enrollments close to urban areas have also been reported by Carman and Polson, Barron and Thomson, Gloudemans, and Gustafson.

Sensitivity of Present Value of Benefits

Variations in contract benefits due to changes in each of the seven factors that determine benefits are compared to baseline conditions in table 4. The present values of benefits for nonbaseline conditions and the percentage deviation from the baseline values are shown for rice, dry pasture, and irrigated crops.

An increase in the rate of land appreciation from 6% to 10% (with other baseline conditions held constant) caused the value of benefits to increase from 25.6% for dry pasture to 36.2% for irrigated crops. Conversely, an increase in land values for only 3% per year decreases benefits by 15.5% for dry pasture and 21.1% for irrigated crops. Thus, benefits are found to vary considerably in response to changes in land value appreciation.

This analysis examines only the sensitivity of benefits to changes in rates of land value appreciation. It does not address the question of whether or not a contract should be accepted under these price patterns when the opportunity costs associated with the loss of a possible sale is considered. Further discussion of this issue is in the concluding section.

Contract benefits are very small for a contract that is in force for only the minimum ten-year period. When the present value of per acre tax savings are expressed as percentages of the initial values of the land, the largest present value of benefits was only 3.9% of the initial value of rice land and the smallest value was 2.4% of irrigated crop land. This result is explained by the nature of the runout formula, which is applied upon notice of nonrenewal. For a ten-year contract, with notice of nonrenewal given at the end of the first year, the assessed value would increase by about 60% of the difference between market- and use-value assessments. The full benefit of use-value assessment would be obtained only in the first year. If a contract is held for twenty years, benefits are substantially greater (from 11.1% of the initial land value for irrigated crops to 16.4% for dry pasture), since full benefits are received for eleven years.

For the thirty-year contract, the present value of benefits varies from 20% to 27.4% of initial land value for irrigated crops and dry pasture, respectively. The thirty-year contract benefits are greater by 67% (dry pasture) to 81% (irrigated crops) than those of the baseline conditions. Thus, the benefits of contract acceptance are highly sensitive to changes in contract length and can be substantial if the contract is held for a long enough period of time.

The effects of landowner discount rates of 6% and 10% were compared to the 8% rate assumed in the baseline calculations. At 6%, benefits increased by approximately 15% for all crops, whereas at 10%, benefits decreased by about 12%.

The effect of a change in the discount rate used in the runout formula, equation (2), is opposite in direction to that produced by a change in the land-owner discount rate. A de-

Table 4. Sensitivity of CLCA Benefits

	Rice		Dry pasture		Irrigated crops	
	$/acre (present value)	% change from baseline	$/acre (present value)	% change from baseline	$/acre (present value)	% change from baseline
Baseline	152.64	—	59.00	—	83.41	—
Land value increase[a] (%/year) (Baseline: 6)						
3	125.81	−17.6	49.86	−15.5	65.82	−21.1
10	199.34	30.6	74.10	25.6	113.57	36.2
Contract length (years) (Baseline: 20)						
10	35.20	−76.9	14.12	−76.1	18.09	−78.3
30	264.97	73.6	98.45	66.9	151.04	81.1
Landowner discount rate (%) (Baseline: 8)						
6	175.47	15.0	67.58	14.5	96.33	15.5
10	133.93	−12.3	51.95	−12.0	72.86	−12.6
Runout formula discount rate[b] (%) (Baseline: 6.75)						
5.75	149.83	− 1.8	57.99	− 1.7	81.75	− 2.0
7.75	155.27	− 1.7	59.95	1.6	84.97	1.9
Reassessment lag (years) (Baseline: 3)						
1	165.26	8.3	63.16	7.0	91.61	9.8
2	158.23	3.7	60.84	3.1	87.04	4.4
4	147.36	− 3.5	57.26	− 3.0	79.98	− 4.1
Property tax rate increase[a] (%)						
1	162.64	6.6	62.75	6.4	89.09	6.8
3	185.30	21.4	71.22	20.7	102.00	22.3
Agricultural income increase[a]						
6%/year	130.87	−14.3	55.10	− 6.6	63.40	−24.0
50% initially	123.56	−19.1	53.79	− 8.8	56.69	−32.0

Source: California, Sacramento County.

[a] Baseline values by cropping activity are from table 1.

[b] The state discount rate is the rate specified for the calculation of property taxes during the runout phase of the CLCA contract (see equation (2)).

crease of one percentage point in the runout formula (from 6.75% to 5.75%) produces a lowering of benefits of only about 1.8% for all crops. The effect of a one percentage point increase in this discount rate is opposite in direction and is of the same magnitude as the one percentage point decrease. Thus, it is seen that both the landowner discount rate and the runout formula discount rate produce small impacts on the levels of contract benefits.

Changing the reassessment time lag from the baseline value of three years to the shortest feasible lag of one year increases the benefits by between 7% (dry pasture) to 9.8% (irrigated crops). A lag of two years increases the benefits by only 3.1% and 4.4% for dry pasture and irrigated crops, respectively, whereas a lag of four years decreases benefits by approximately the same amount. It is concluded that more frequent reassessment of parcels would have little effect on contract benefits.

A 1% per year increase in the property tax rate results in increased benefits from 6.4% (dry pasture) to 6.8% (irrigated crops). A 3% per year increase in the property tax rate increases the benefits by approximately 21% for all crops studied. Although the absolute tax bill of the landowner increases with increasing property tax rate, the contract benefits (relative to the no-contract situation) also increase. Since a 3% annual increase would almost double the property tax rate in twenty years, there is some question as to whether such a rate of increase could be sustained. Accordingly, changes in property tax rates are felt to have limited potential for influencing the level of benefits under the CLCA.

Increases in agricultural income, if not fully capitalized into increases in market value, reduce the difference between market and use-value assessment, and hence the size of the CLCA benefits. Income is the only variable to cause considerable between-crop differences in benefits. A 6% per year increase in agricultural income caused less than a 7% decrease in benefits for dry pasture but a 24% decrease for irrigated crops. An initial increase in income of 50% produced a similar pattern, with benefits for dry pasture decreasing by only 8.8%, while those for irrigated crops decreased by 32%. Changes in rice benefits fell between these values for both income changes. Since the CLCA agricultural assessed values depend on agricultural income, the differences in benefit changes among the crops can be explained by the ratio of agricultural to market assessed values, with the largest change in benefits occurring for the smallest ratio of agricultural to market assessed value.

Sensitivity of Benefits to Interactions of Selected Factors

Two criteria were established as the basis for selecting among the many possible combinations of factors that influence the present value of CLCA benefits: the degree to which the parameters are controllable by policymakers, and the impact on benefits as determined by the single variable sensitivity analysis of the previous section. The parameters are classified into three categories in terms of policymaker control: those directly controllable by policymakers, those partially controllable, and those not controllable. Factors under the control of policymakers are the contract length, reassessment lag, and the discount rate used in the runout formula. Variables largely beyond the control of decisionmakers are the agricultural income and the landowners' discount rate, while the property tax rate and market value appreciation of land form an intermediate category, since they are usually determined by broader economic forces but can be influenced by policymakers.

Based on the single variable sensitivity analysis, only two variables are considered to have significant potential for influencing the present value of benefits: contract length and the market value appreciation of land. The landowner and runout formula discount rates and the reassessment time lags are found to be of little significance, while the remaining variables (property tax rate and agricultural income) are found to have a limited impact on benefits. Based on these criteria, the logical candidates for interaction analysis are contract length, land values, and (to a lesser extent) the property tax rate.

As seen in table 5, changes in appreciation in market value under a ten-year contract have little impact on benefits, compared to the ten-year contract results of table 4, indicating the dominant effect of the ten-year contract. By contrast, a strong interactive effect is demonstrated when a thiry-year contract is combined with a 10% increase in land values, with benefits increasing from two to two-and-one-half times the highest levels demonstrated in any of the single variable sensitivity results. Benefits are approximately three times the baseline values when a thirty-year contract is combined with a 10% per year appreciation in market value of land. This represents an increase in benefits of from 62% (dry pasture) to 86% (irrigated crops) over the additive effect of the two variables.

The effect on benefit changes is noticeably diminished when contract length is considered together with the property tax rate rather than with land value appreciation. However, with a thirty-year contract, the effect of the property tax rate is still significant. Benefits are approximately double the baseline values when a 3% increase in the property tax rate is added. This increase in value is approximately 50% above the additive effect of the two factors taken separately. By contrast, a ten-year contract provides essentially the same level of benefits regardless of the change in property tax rate.

When the appreciation in market value of land and the changes in property tax rates are taken together, the results are approximately the same as the individual additive effects. For low rates of appreciation in market value of land, the decrease in benefits are in part counteracted by the effect of increased property taxes, with results within 5% of what would be obtained by adding the individual impacts. The same result is observed for the higher rate of land appreciation with the low property tax rate increase. Slight interactive changes result when the high land appreciation rate is combined with the high property tax increase. Benefits are approximately 10% less than would be true for a strictly additive impact. We are able to conclude that for higher rates of land appreciation and property taxes benefits under the CLCA can be substantial (and addi-

Table 5. Sensitivity of CLCA Benefits to Combinations of Parameters

	Rice		Dry pasture		Irrigated crops	
	$/acre (present value)	% change from baseline	$/acre (present value)	% change from baseline	$/acre (present value)	% change from baseline
Baseline	152.64	—	59.00	—	83.41	—
Land value appreciation and contract length						
3%/year with:						
10-year contract	33.09	−78.3	13.43	−77.2	16.72	−80.0
30-year contract	189.86	24.4	73.69	24.9	102.27	22.6
10%/year with:						
10-year contract	38.34	−74.9	15.16	−74.3	20.13	−75.9
30-year contract	421.38	176.1	150.01	154.3	252.60	202.8
Contract length and property tax rate						
10-year contract with property tax rate increase of:						
1%/year	36.37	−76.2	14.51	−75.4	18.53	−77.8
3%/year	38.86	−74.5	15.18	−74.3	19.45	−76.7
30-year contract with property tax rate increase of:						
1%/year	299.13	96.0	109.94	86.3	169.56	103.3
3%/year	385.14	152.3	137.81	133.6	215.90	158.8
Land value appreciation and property tax rate						
3%/year land value increase and property tax rate increase of:						
1%/year	132.94	−12.9	52.96	−10.2	69.81	−16.3
3%/year	149.55	− 2.0	59.44	− 0.7	78.78	− 5.6
10%/year land value increase and property tax rate increase of:						
1%/year	213.80	40.0	79.60	34.9	122.31	46.6
3%/year	247.45	62.1	91.69	55.4	142.35	70.7

Source: California, Sacramento County.

tive), ranging from 55% to 71% above the baseline conditions for dry pasture and irrigated crops, respectively.

Conclusions and Policy Implications

For the land values and incomes prevailing in the study area, the acceptance of a CLCA contract can reduce the tax bill of a landowner by as much as 50% to 80% for the crops analyzed. However, the present value of contract benefits does not become substantial unless the contract is held for twenty years or more. For a minimum term contract of ten years, the benefits are always less than 5% of the initial land value.

Because a long-term contract commitment is required to obtain substantial CLCA benefits, the opportunity costs associated with foregoing a favorable sale assume particular significance. This is especially true since results presented in this paper indicate that unenrolled lands show a higher potential tax benefit than enrolled lands—suggesting that the enrollment decision is influenced by other than simply the size of current tax reductions.

Because a wide variety of land price patterns and assumptions about the timing of sale are possible, determination of whether contract acceptance is justified is complex and does not lend itself easily to calculations of "break-even" benefit levels. In a previous study (Schwartz, Hansen, and Foin), opportunity costs were examined by comparing the present value of contract acceptance (assuming sale of land at the end of twenty years) to the present value of nonacceptance and sale during the twenty-year period. Several general conclusions emerged. If the rate of price increase is above the landowners' discount rate

and the increase continues throughout the contract period, the contract alternative is preferred. Nonacceptance of a contract was favored for sharply peaked patterns wherein the local maximum in the present value of the noncontract alternative created by the price peak exceeded the present value of the land plus contract benefits at the end of the twenty-year period. However, if the sale was not assumed to be reasonably close to the peak, contract acceptance was often favored.[6] Furthermore, modest price increases occurring after the peak could also cause the contract alternative to become the preferred choice. Our analysis indicated that a substantial number of situations were likely to favor contract acceptance.

In a second study (Hansen and Schwartz), we found enrollment rates at the rural-urban fringe to be much lower than would be expected if enrollment decisions had been based on a long-range economic comparison of the alternatives. Our conclusion, based on the economic analysis and surveys of landowners, was that unrealistic land development expectations were held by a large proportion of landowners at the urban fringe.

One possibility for making the CLCA contract relatively more attractive to the landowner is to increase benefits directly—an approach that is likely to entail considerable tax shifting. As an alternative, the levels of CLCA benefits could be altered by changes in the parameters that determine these benefits. Of those parameters under the control of policymakers, the reassessment lag and runout formula discount rate were found to have little impact on levels of benefits. Only the length of contract was found to be of significant influence. A twenty-year contract yields benefits that are as much as 300% greater than those from a ten-year contract. However, previous research has shown that substantial enrollment is lost (or would be lost) by longer minimum term contracts (Schwartz et al.). Since a ten-year contract is extended each year unless a notice of nonrenewal is filed, there is no need to offer contracts of longer minimum term. The shorter minimum term provides greater flexibility to the landowner, while allowing the same level of benefits to be reached through renewal. Thus, policymakers who wish to encourage greater enrollment should implement the shorter term renewable contracts.

Agricultural income and the landowners' discount rate are variables largely beyond the control of decisionmakers. Although land-use control policies can alter agricultural income to some degree and can affect the discount rate by affecting the uncertainty of permissible land uses, these variables are primarily determined by broader economic conditions. Our results indicate that policymakers need not be greatly concerned with changes in these exogenous variables. Quite large changes in the landowner's discount rate are required before a noticeable impact on benefits occurs. Although large increases in agricultural income are seen to reduce benefits substantially in some cases, the net effect is probably to lessen the pressures to sell prematurely.

The property tax rate and land value appreciation variables are usually determined by broader economic forces but can be influenced by policymakers. Benefits are only moderately sensitive to changes in the property tax rate, with the higher levels noted in the property tax-contract length interactions being largely attributable to the contract length. Since the property tax rate is an extremely blunt instrument for influencing enrollment, and since an increase in the rate will produce a larger actual tax bill for the landowner (along with the relative increase in benefits), such a measure has little appeal for influencing benefits. Land values can have a major impact on the level of benefits, with interactions with property taxes and contract length also producing marked increases. However, the limitations of these latter two variables for policy purposes should again be noted.

The results of this study lead us to the conclusion that there is little opportunity for policymakers to influence enrollment (other than by altering direct benefits) except through measures that influence land values or the development expectations of landowners. Development expectations could be altered by providing greater information about the CLCA and land price trends. Alternatively,

[6] As examples, assuming agricultural income of $60 per acre and a land price that increases at a rate of 10% per year, land with an initial value of $1,017 per acre, when held for the twenty-year contract period, has a present value of $2,691 (including CLCA contract benefits and income). In contrast, if noncontracted land undergoing the same price changes was sold in year 10, and the proceeds, less capital gains taxes, were reinvested at an after-tax return of 6%, the present value would be $1,734. If the price pattern exhibited a 5% to 10% increase through year 6, a 50% increase in year 7, then a drop to year 6 levels, the sale at optimal time (year 7) would produce a present value of $1,780 for noncontracted land. If, instead, sale was in year 5 instead of year 7, the present value of noncontracted land would be only $1,297. These compare with $1,387 for contracted land.

more stringent land-use regulations could be implemented. However, to the extent that more effective planning and enforcement of zoning is required to decrease expectations and produce greater enrollment under the CLCA, the use-value assessment, by itself, must be considered to have little potential for effectuating desired land use patterns at the urban fringe.

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An Economic Analysis of a Regionalized Rural Solid Waste Management System

William E. Hardy, Jr., and Curtis L. Grissom

A quantitative model is developed to examine the possibility of cost savings through cooperative efforts in collecting and disposing of solid waste material. Heuristic algorithms are used to determine the best locations for landfills and the best routes for the collection trucks to follow in serving the five-county study area. The results of the economic analyses indicate that a regional system for solid waste collection and disposal can be justified from a cost standpoint.

Key words: location analysis, regional planning, solid waste management, vehicle scheduling.

The availability of adequate public services such as solid waste disposal systems, sewer and water systems, transportation networks, quality education, and medical care is a prime factor affecting the development of many rural areas. In some localities, necessary services are not available, or if they are present, they are of very low quality. Many sparsely populated rural areas, because of their low income base, simply cannot afford to provide adequate levels of all needed services and, as a result, will likely remain poor and underdeveloped.

Emphasis is presently being placed upon the concepts of regionalism and community cooperation in planning for the provision of certain public services. Legislation passed in recent years at both the federal and state level has been designed to encourage such cooperative efforts among local governing bodies so that unnecessary duplication might be avoided and better quality services provided.[1]

Renewed interest has been generated among researchers regarding public service delivery problems. Jones and Gessaman present a brief survey of recent research in this area with emphasis directed toward those studies investigating possible cost reductions through consolidation of local governmental efforts. They indicate that the findings of these efforts point to lower costs through economies of scale up to certain levels for most services but that consolidation cannot be supported as a universal means for reducing costs. In a study examining the solid waste management problem, Schreiner, Muncrief, and Davis found that there are significant economies of size in the disposal process, but the the cost of collection was more closely related to customer density than to the size of the service area.

This paper continues the discussion of rural public service delivery problems through presentation of the results of a research project designed to determine the least cost solid waste management system for a selected five-county area of northwest Alabama. The study area, Alabama Regional Planning District 1, is predominately rural with a single urbanized area located in portions of two of the counties. The data presented in table 1 give the geographic area, population, and expected annual solid waste for the five counties considered. This multicounty area is typical of many regions of the United States, thus the results of the research could be applicable nationwide.

The Theoretical Model

The basic computational logic followed in the analysis was to develop a set of feasible solu-

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[1] The Housing and Community Development Act of 1974 and the Rural Development Act of 1972 are federally sponsored laws that have sections encouraging cooperative efforts. Individual states have laws permitting or requiring regional planning districts. In Alabama, Act 1126, passed in 1969, created such organizations.

Table 1. Area, Population, and Expected Annual Solid Waste for Counties in Alabama Regional Planning District 1

County	Geographic Area (sq. mi.)	Population Rural	Urban	Total	Expected Solid Waste (tons)
Lauderdale	661.8	34,080	34,031	68,111	249.59
Colbert	596.4	20,782	28,850	49,632	189.61
Franklin	643.9	16,119	7,814	23,933	86.90
Marion	743.0	17,547	6,241	23,788	84.78
Winston	633.0	12,520	4,134	16,654	59.10

Source: Area and population data are from *County and City Data Book, 1972* (U.S. Dep. of Commerce). Expected solid waste data were obtained by multiplying population by appropriate waste generation coefficients (Muhich).

tions, calculate the total cost for each, and then compare these to determine the least cost organizational pattern. This is similar to the plant location and assembly cost concepts presented earlier by Stollsteimer and later modified by Chern and Polopolus.

Each feasible solution and resulting total cost data was obtained through the use, in a stepwise fashion, of two basic quantitative models. First, a location model was used to determine the best locations for specified numbers of sanitary landfills. Second, a routing algorithm was employed to determine the best routes for collection trucks to travel in collecting the solid waste for each locational pattern established by the first model. The authors realize that better solutions and further cost savings for the given problem might be realized through a simultaneous or iterative use of the two models; however, such methodology is currently unavailable.

The Location Model

The problem involved in determining the best locations for specified numbers of sanitary landfills can be referred to the general class of theories and models known as the "location-allocation problem." With these problems, the best locations for specific numbers of central facilities are to be found, and the assignment of the flows of goods between these facilities and another set of points is to be determined. If the locations are already known, then the flow assignment problem becomes the ordinary linear-programming transportation problem. The classical spatial economics problem presented by Weber (Friedrich) can handle the pure locational problem that exists if the flow assignment is known, but the location of the central facility is unknown.

Scott presents a detailed explanation of the basic and extended location-allocation systems and discusses appropriate methodology for solving these problems. Optimizing methods are available, but he emphasizes that "location-allocation problems are frequently soluble by heuristic programming" (p. 111). This is particularly true for large scale models.

The model used to determine the best locations and pickup point assignment for this research was based upon the heuristic procedure presented by Shannon and Ignizio and programmed by Hardy (1973). The objective of minimizing total transport miles may be presented as

$$(1)\quad \min TTM = \sum_i \sum_j [[C_{ij}(X_{ij})]\,[Z_{ij}Y_j]].$$

This objective is consistent with the "central place" theories and gravity models used by economic geographers and market planners (ReVelle and Swain) in using distance as a surrogate measure for cost. The C_{ij} values represent the distance that each unit of solid waste, X_{ij}, must be transported from collection point i to sanitary landfill j, while Z_{ij} is a zero-one variable that takes on a positive value if waste from i is transported to j. The variable Y_j is also zero-one, being nonzero if a landfill is located at j.

Attainment of the objective was limited by the constraints

$$(2)\quad \sum_j X_{ij} \geq D_i,\ (i = 1, 2, \ldots, M),$$

$$(3)\quad \sum_j Y_j \leq F,$$

and

$$(4)\quad \sum_j Z_{ij} \leq 1,\ (i = 1, 2, \ldots, M).$$

Equation (2) assures that the total waste, D_i, at all M pickup points is collected. The con-

straint value, F, in equation (3) specifies the number of landfills to be located, and equation (4) prevents the waste from each pickup point from being delivered to more than one landfill—no multiple delivery points.

The complete location analysis required the assimilation of several types of data. Information concerning the location and quantity of waste to be collected, the location of potential landfill sites, and the most direct road distances connecting all waste collection points and potential landfills sites had to be obtained.

Census enumeration district data and maps giving population distribution and density for the total study area were combined with national average coefficients (Muhich), giving expected daily waste generation for rural and urban areas, to calculate the amount and location of residential waste that could be expected from the households of the area. National average waste generation values were used because the five counties considered in the study did not have accurate data to reflect their actual collection volume.

It was assumed that individuals would deposit their solid waste in containers at one of 237 collection points that were selected on the basis of population location and density and that collection trucks would service these containers twice weekly. It was necessary to assume that a containerized collection system would be used, since determining the location of each house and designating it as a pickup point would have been practically impossible and computationally infeasible. It was assumed that one or more containers would be placed at each collection point with the number of containers being dependent upon the expected amount of waste for that area.

General soils maps prepared by the U.S. Department of Agriculture Soil Conservation Service were utilized to determine potential landfill sites (Muscle Shoals Council of Loc. Govt.). These maps indicated areas within the five-county region that were geologically suited for landfills. Thirty-four potential sites were specified.

County highway maps were used to determine the most direct all-weather routes connecting all collection points with each other and with each potential landfill site. The distances from each point to all adjacent points were measured manually from the maps. All other connecting distances were obtained by using a computerized shortest-path algorithm (Hardy 1972). A total of 73,441 (271 × 271) connecting distances were required for the complete analysis.

The objective in determining the best locations for each of the specified number of sanitary landfills was to establish those locations that would minimize total travel if a single trip was required to deliver the waste from each collection point to the sanitary landfill. Thirty separate location analyses were completed, giving the best single, two, and three sanitary landfill locations for each county and for three subregional multicounty combinations. Subregional multicounty combinations were considered because it was felt that cooperative efforts could exist among areas smaller than the regional level. The best locations for one through six landfills were found for the five-county region taken as a whole. In addition to indicating where each landfill should be located, the location analysis permitted the determination of the service area boundaries and the necessary size for each landfill to accommodate the expected waste from the area for ten years. These landfill capacity needs were estimated using guidelines established by Carley.

The Routing Model

A substantial portion of the total cost of operating a solid waste management system is incurred during the collection process (Huie). Because of this, it is imperative that collection vehicles be used as efficiently as possible. The problems encountered in designing an economically efficient collection system are normally classed with the theories referred to as "transportation-routing problems." In this problem area, the decisionmaker must schedule an existing fleet of vehicles, each with a capacity constraint, to visit a set of stops or destinations and pickup or deliver goods or services at each stop such that only one vehicle visits each stop. The objective is to minimize the total cost of delivery. Normally, it is assumed that cost is proportional to distance.

A detailed survey of the current state of the art regarding routing problems is presented by Turner, Ghare, and Fourds. Turner and his associates point out that there are models available that will give optimal solutions to vehicle-scheduling problems, but that for these methods computational time increases exponentially with problem size.[2] Because of

[2] They further indicate that most of these models that guarantee optimality are based upon the conventional "traveling salesman

this limitation, most large-scale problems, as with location-allocation problems, have been solved heuristically. One of the first and most extensively referenced of such models was developed by Clarke and Wright. Their heuristic procedure has served as the basis for many successful applications.

A computerized routing algorithm developed by Hallberg and Kriebel and based upon the Clarke and Wright method was selected for use in the routing-analysis section of this study. The program permits great flexibility in problem formulation and is computationally efficient. The basic logic followed by the procedure in route development is as follows. The maximum cost solution is first assumed. With this assumption, all pickup points or stops are each placed on individual routes so that the total cost would be

$$(5) \quad TC = 2 \sum_j C_{oj}$$

for symmetrical problems, and

$$(6) \quad TC = \sum_j C_{oj} + \sum_j C_{jo}$$

for asymmetrical problems. In equations (5) and (6), C_{oj} and C_{jo} represent the relevant costs of travel from the origin to a stop and from a stop to the origin, respectively.

The next step is to develop savings coefficients, S_{ij}, which represent the amount of savings if two stops are joined on a route. The savings for connecting stops i and j would be

$$(7) \quad S_{ij} = C_{io} + C_{oj} - C_{ij}.$$

Savings coefficients are calculated for all possible combinations of stops taken two at a time and arranged in descending order. Route development then begins with pickup points being linked to a route on the basis of maximum savings coefficients. For the solid waste management problem considered by this study, points were added to routes until either truck capacity (thirty cubic yards) or travel time (eight hours) or both were violated. A more detailed explanation of the computation procedure is presented by Schruben and Clifton.

A truck-routing analysis was completed for each sanitary landfill locational pattern established by the location model. In addition to generating the best collection routes, these routing analyses aided in determining how many trucks would be required for each landfill operation and the total number of miles that each would travel. This information was necessary for establishing total investment and operating costs involved in the collection process.

problem" and rely upon the techniques of integer and dynamic programming and branch and bound programming.

Research Results

The results of the thirty location and routing analyses provided input for budgets that were prepared to permit cost comparisons for each alternative solid waste management system. The data presented in table 2 illustrate the total initial investment and annual operating cost data for specified numbers of sanitary landfills in each individual county, each multicounty subregional system, and the total five-county region.

The operating cost data not only indicated that there are definite economies of scale to be realized in the disposal phase of the total system but also that the costs of operating the collection system are influenced by the size of the area being served and population density. These conclusions are consistent with the findings of Schreiner, Muncrief, and Davis.

When viewing the estimated operating costs for each of the individual counties, it can be seen that as the average size of the landfill is decreased (an increased number of landfills for a given volume of waste) and the average size of the collection area is decreased, both disposal and collection costs increase. These increases indicate inefficiencies if more than one landfill is established in each county. The absolute and relative increases in collection costs as the number of landfills is increased is lowest for Lauderdale County, the most urban and densely populated.

When the three subregional multicounty combinations are considered, increased costs from decreasing the size of landfill operations is still apparent, but the costs of collection tend to decrease as the number of landfills is increased. For the Colbert County and Lauderdale County combination, there is little change in the annual collection cost as the number of disposal systems is changed. This again indicates the influence of population density on transportation costs. The more sparsely distributed population of the counties included in the other two combinations causes increased travel cost as the service area of each landfill is increased.

Table 2. Initial Investment and Annual Operating Costs for Specified Numbers of Landfills

Counties Served	Number of Landfills	Initial Investment	Annual Operating Costs Collection	Disposal	Total
Colbert	1	$283,480	$ 38,495	$ 64,480	$102,975
Colbert	2	388,225	57,274	91,996	149,270
Colbert	3	514,557	87,842	121,464	209,306
Franklin	1	218,405	40,087	49,510	89,597
Franklin	2	332,885	55,634	78,823	134,457
Franklin	3	424,387	71,561	108,176	179,737
Lauderdale	1	429,630	60,812	92,780	154,592
Lauderdale	2	492,645	62,571	109,229	171,800
Lauderdale	3	595,563	78,225	139,536	217,761
Marion	1	222,730	38,914	50,276	89,190
Marion	2	337,275	57,283	79,498	136,781
Marion	3	428,627	71,477	108,821	180,298
Winston	1	203,450	37,565	45,896	83,461
Winston	2	317,715	55,995	72,178	128,173
Winston	3	409,967	67,566	103,982	171,548
Col., Lau.[a]	1	613,535	103,483	136,533	240,016
Col., Lau.	2	697,820	107,933	146,716	254,649
Col., Lau.	3	799,969	106,232	171,172	278,404
Win., Mar., Fkl.[b]	1	486,275	126,505	86,897	213,402
Win., Mar., Fkl.	2	540,775	117,233	123,212	240,445
Win., Mar., Fkl.	3	660,674	95,779	142,456	238,275
Win., Mar., Fkl., Col.[c]	1	696,950	164,016	137,203	301,219
Win., Mar., Fkl., Col.	2	732,100	143,840	157,019	300,859
Win., Mar., Fkl., Col.	3	849,699	136,291	173,905	310,196
Region[d]	1	1,130,195	249,319	236,661	485,980
Region	2	1,058,895	213,740	233,535	447,275
Region	3	1,139,495	218,285	238,952	457,237
Region	4	1,266,095	226,129	276,468	502,597
Region	5	1,379,695	233,343	319,154	552,497
Region	6	1,470,895	237,206	356,985	594,191

[a] Colbert, Lauderdale.
[b] Winston, Marion, Franklin.
[c] Winston, Marion, Franklin, Colbert.
[d] All five counties.

Economies of size appear to be evident in both phases of the total system when all five counties were considered as a single region. The cost savings of a relatively large collection system in the more densely populated counties appear to compensate for the increased costs of the large system in the more rural counties. These cost relationships are illustrated in figure 1. It is interesting to note that the regional operation with two landfills gives the minimum annual operating cost for both collection and disposal.

The investment-cost data for the alternatives presented in table 2 would be valuable to the decisionmaker in deciding how much initial capital he would need to get the system going. The increases in these data are fairly consistent with the changes in total operating costs for each respective system. Because of this and the inclusion of interest and annual depreciation for capital items in the operating cost budgets, the total operating-cost figure should be used for selecting the least cost system.

The major objective of the research was to determine the least cost collection and disposal system for the total five-county area. The data presented in table 3 represent the total annual operating costs for various systems that serve the entire five-county region. These cost values indicate that definite dollar savings can be realized if the five counties considered in the study cooperate in the operation of a solid waste management system. This least cost system from the regional standpoint is to have two regional sanitary landfills. This alternative, with an estimated annual operating cost of $447,275, would per-

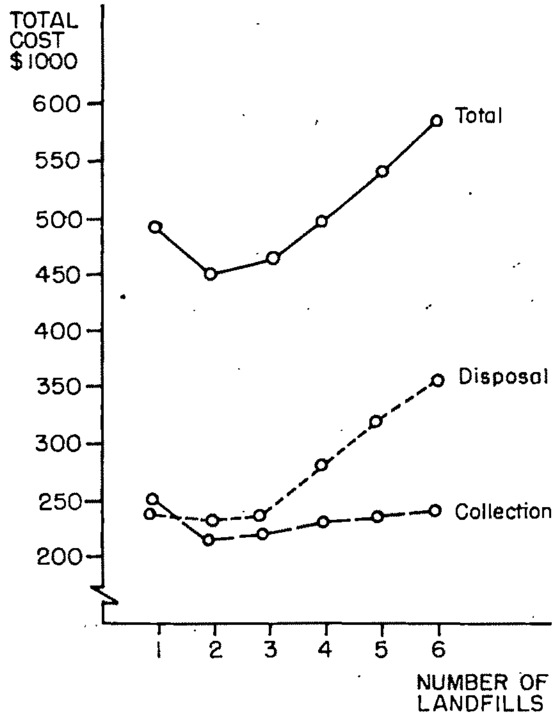

Figure 1. Annual operating cost for specified numbers of landfill operations in the five-county region

mit the counties to save more than $6,000 annually over the second best alternative and more than $72,000 over the alternative in which each provides its own system. In fact, there are at least ten possible systems that have a lower annual operating cost than the combined individual county system.

Summary

The concept of regional cooperation for the provision of necessary community services is presently receiving emphasis. The major justification normally given for such cooperative efforts is that the cost of providing the service might be reduced and better services be provided. Cost savings could be realized through less duplication of large and expensive equipment and by the regional system being large enough to operate with maximum economic efficiency.

The results of the study presented in this paper verify that there are definitely economies of scale to be realized in the disposal phase of a solid waste management system and that costs of collection are dependent on population density and the size of the service area. The combined collection and disposal costs indicated that a regional system can be justified for the selected study area. The least cost system for the five-county study area is to have two regional landfills. The annual costs associated with this system, $447,275, are substantially less than the $519,815 estimated for the system with each county operating independently. Nine other regional and subregional systems have lower annual operating costs than the combined individual county system, emphasizing the possibility for cost savings through cooperation.

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Table 3. Annual Operating Costs for Solid Waste Management Systems Serving the Five-County Region

System Combination			
Counties	Number of Landfills	Annual Operating Cost	Total Annual Operating Cost
Region[a]	2	$447,275	$447,275
Win., Mar., Fkl.[b]	1	213,402	
Col., Lau.[c]	1	240,016	453,418
Win., Mar., Fkl., Col.[d]	2	300,859	
Lauderdale	1	154,592	455,451
Win., Mar., Fkl., Col.	1	310,219	
Lauderdale	1	154,592	455,811
Region	3	457,237	457,237
Win., Mar., Fkl., Col.	3	310,196	
Lauderdale	1	154,592	464,788
Win., Mar., Fkl.	1	213,402	
Col., Lau.	2	254,649	468,051
Win., Mar., Fkl.	3	238,275	
Col., Lau.	1	240,016	478,291
Region	1	485,980	485,980
Region	4	502,597	502,597
Colbert	1	102,975	
Franklin	1	89,597	
Lauderdale	1	154,592	
Marion	1	89,190	
Winston	1	83,461	$519,815

[a] All five counties.
[b] Winston, Marion, Franklin.
[c] Colbert, Lauderdale.
[d] Winston, Marion, Franklin, Colbert.

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Pests as a Common Property Resource: A Case Study of Alfalfa Weevil Control

Uri Regev, Andrew P. Gutierrez, and Gershon Feder

The biological interactions of a pest-plant system are incorporated into an optimal pest-control model, using data and estimated parameters specific to the alfalfa weevil. Due to the externalities inherent in situations involving common property resources, different solutions are obtained for private and societal formulations of the optimization problem. In contrast to current pesticide-spraying practices, it is shown that pesticide should be applied early in the season, before any damage can be observed.

Key words: aestivation, alfalfa weevil, common property resource, pesticide.

Recently, problems in pest management have attracted considerable attention in economic literature. Entomologists have concentrated on understanding the biological characteristics of the pest-crop relationships.[1] Economists have long recognized pest populations as detrimental common property resources. (Detailed definitions of common property resources and a development of the economics of common property resources are found in Brown; Cummings; Gordon; Plourde; Quirk and Smith.) Many have focused their attention on some of the economic aspects relating to economic thresholds (Headley; Hall and Norgaard), pest resistance (Taylor and Headley, Hueth and Regev), and pest-predator relationships (Feder and Regev). Others have used various optimization methods to solve single-season pest management problems (Shoemaker 1973a, 1973b; Talpaz and Borosh).

This paper describes an economic optimization model that incorporates detailed biological input specific to the alfalfa weevil. Using the available biological data and estimates, the problem is examined from a societal point of view and recognizes specific common property characteristics of the pest. The analysis points out the gap between private and societal control policies, offers estimates of shadow prices, and indicates a direction toward optimal pest-control policy.

Many features of pest-control problems lead to divergence between the optimal policy of a single decisionmaker and the society as a whole. The major types of externalities involved in pest-control problems include interseasonal dynamics, biological relationships with other pests and predators, environmental contamination by pesticide residues, resistance to chemical pesticides, effects of control on neighboring fields, and health problems relating to pesticides.[2] In this paper, attention is focused on only one of these aspects—stock externalities (Smith). These externalities, which are common among highly mobile pests, result from the dependence of population dynamics of the pest between seasons on the total population level in the region. During the season the farmer can control only the pest population in his field, which is, presumably, a small fraction of the total.[3] From an intersea-

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[1] A survey of this literature is beyond the scope of this paper. Most of this literature is pest specific where an attempt is made to understand and model a given species. References on the biology of the Egyptian alfalfa weevil [*Hypera brunneipennis (boh.)*] can be found in Gutierrez et al.

[2] The extent of some of these externalities depends on the degree of pest mobility between fields.

[3] Intraseasonal pest migration between fields is negligible.

sonal point of view, the pest is a nonappropriable resource leading to a gap between marginal private and social benefits.

The Biological Model

A biological model for the relationships between the pest and the plant and the mortality effects of pesticide application on the pest is developed in this section. While the formulation is made specifically for the alfalfa weevil, the major pest for alfalfa in California, it can be generalized and adopted for many other pest problems as well. For a detailed description of the life cycle of the Egyptian alfalfa weevil, see Gutierrez et al.

Biological Background

Alfalfa is a woody perennial and is grown for hay and/or seed. The alfalfa stand grows for three to five years, at which time it has to be replaced because it has been invaded by weed species. The crop normally goes through two phases: a winter dormant period and a vegetative phase between harvest dates.[4]

Alfalfa regrowth during the spring begins when night temperatures are consistently above its thermal threshold (42° F.) and severe ground frosts have ceased. The rate of growth of alfalfa (i.e., dry matter production) is regulated by physiological time, measured in degree days and denoted by D° (Campbell et al., Wang). Alfalfa grows approximately 1,000D° between harvest dates.[5]

The alfalfa weevil has one generation per year. The adult spends the hot summer in sheltered places usually out of the alfalfa fields. It emerges to feed and lay eggs during the autumn after night temperatures of less than 42° F. occur (Gutierrez et al.). The population of adults migrates into the field at a rate that is a linear function of D°, reaching a maximum at about 180D°. The adult weevils mature, and females begin laying eggs after approximately 400D° and continue laying them until their death. A single larva hatches from each egg and begins to consume leaves at a rate that increases approximately in a geometric pattern over D°. Since larvae cannot survive a frost, all larvae that hatch before the last frost die prematurely and are not considered here. After 360D° of feeding, the larva is transformed into a nonfeeding pupa and, after a period, reaches the adult stage. The adult emerging from the pupa feeds for a while and then aestivates (summer hibernation), ending the year-long cycle. Adult feeding (both newly hatched and overwintering adults) is relatively minor and will be ignored in this study.

In the following, the behavior of the three major components of the system (the adult pest, the larva, and the plant), their interrelationships, and how they are affected by pesticide application are formulated. The specific algebraic forms chosen in this application, together with estimates of many of the parameters, rely heavily on a simulation model for the alfalfa weevil developed by Gutierrez et al. A detailed explanation of the parameters and data sources is given in the appendix.

The Time Dimension

As the developmental process of both the plant and the pest strongly depends on temperatures above certain thresholds (42° F. and 44.7° F., respectively), the physiological time scale of the plant has been used for both rather than calendar time. The time unit t is defined by a fixed interval, 60D°.

The choice of the initial time period, t_0, is related to the last frost and is based on the fact that frost suppresses the plant and kills the larvae, but not the adults. No damage is done by larvae prior to the last frost because the regrowth of the crop begins at the same time. Thus, t_0 is chosen at 240D° (four time intervals) before the last frost, which is the time interval from egg oviposition to hatching of the larvae because any larvae appearing before the last frost will not survive. The growth of the plant resumes following the last frost ($t = 4$).

In the single-season decision problem, the horizon, t_f, is chosen as the (physiological) time of the first alfalfa cropping. This is based on the observation that damage from the alfalfa weevil is negligible after that time.[6]

The Adult Stage

The dynamics of the adult weevil in the absence of control are presented in figure 1.

[4] When the alfalfa is grown for seeds, there is an additional phase. This paper deals primarily with alfalfa grown for hay.

[5] In the summer 1,000D° is approximately one month, and in the late winter and spring 1,000D° is approximately 3½ months.

[6] Although earlier cropping could be used as a pest control means (t_f becoming a decision variable), this possibility is not pursued here since the primary focus is on chemical control only.

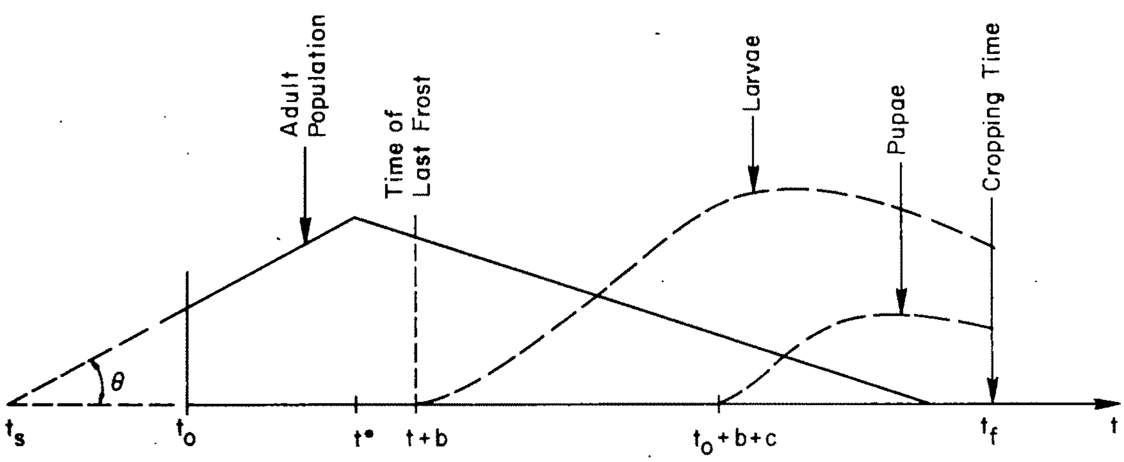

Figure 1. Time phenology of egyptian alfalfa weevil

The effect of pesticide application on the pest population is estimated by a dosage response curve (kill function). Using field data from Cothran and Christiansen, it has been estimated by the form $k = 1 - e^{-\alpha x}$, where k is the percentage of pests killed and x is the amount of pesticide (Hueth). Larvae have a higher susceptibility rate than adults.

The dynamics of the adult pest is then given by

$$
(1) \quad y_{t+1} = \begin{cases} y_t e^{-\alpha x_t} + \theta & t_0 \leq t \leq t^* - 1 \\ y_t e^{-\alpha x_t}\left(1 - \dfrac{1}{t^+ - t}\right), & \\ & t^* \leq t \leq t^+ - 1 \leq t_f \end{cases}
$$

$$y_{t_0} = (t_0 - t_s)\,\theta,$$

where y_t = number of adult pests per square foot at the beginning of the tth time period before spray, x_t, is applied, x_t = amount of pesticide applied (ounces per acre), θ = infestation rate (number of pests immigrating per square foot per time period), t_s = time of arrival of the first pest, t_o = initial time of the problem ($t_s < t_o$), t^* = time of peak adult population, t^+ = time of zero adult population, and t_f = time of cropping. Equation (1) reflects the effect of pesticide application on the natural adult pest level, which is presented in figure 1. The parameter θ (infestation rate) plays a crucial role in the problem, as it determines the severity of the potential pest damage.

Eggs, Larvae, and Pupae

The rate of oviposition, E_t, depends upon whether conditions and the age composition of the adult pests (see appendix). After time interval b, the eggs hatch, and the number of first-day larvae, L_t, in each time period is given by

$$(2) \quad L_t = y_{t-b}\, e^{-\alpha x_{t-b}}\, E_{t-b}$$

for $t_o + b \leq t \leq t_f$; otherwise, $L_t = 0$.

The number of larvae that become pupae, Z_t, at each time interval is the number of first-day larvae that survive all pesticide applications throughout their lifetime:[7]

$$(3) \quad Z_t = L_{t-c}\, e^{-\delta \Sigma x_\tau}$$

for $t_o + b + c \leq t \leq t_f$; otherwise, $Z_t = 0$, where δ = susceptibility parameter for larvae, c = length of larval life, and Σx_τ = total insecticides applied in time period $t - c + 1, \ldots, t$, which spans the lifetime of larva that becomes a pupa at time t.

Leaf Mass Consumed by Larvae

Consumption of leaf mass by a single larva is estimated by a geometric function of its age, and total consumption of leaf mass by all larvae (v_{t+1}) in period $t + 1$ is given by

$$
\begin{aligned}
(4) \quad v_{t+1} &= v_t\,(1 + a)\, e^{-\delta x_t} + \rho\, L_t \\
&\quad - Z_t\, \rho\,(1 + a)^c \\
&\text{for } t_0 + b - 1 \leq t \leq t_f - 1, \\
v_{t_0+b-1} &= 0,
\end{aligned}
$$

[7] Equations (1) through (4) slightly overestimate the population levels (after the adult peak), since natural mortality within the period is not considered. This, however, is not expected to cause a significant error. Equation (4) is a good approximation in the economically relevant region where $x_t > 0$ for some t. If $x_t = 0$ for all t, then the number of pupae is greatly reduced by internal competition; however, in that case the crop is completely destroyed.

where a = rate of increase in leaf consumption by the larvae and ρ = leaf mass consumption by a first-day larva during one time interval. The first term on the right-hand side of equation (4) represents the consumption of larvae that survived from the preceding time period. However, this term also includes consumption by larvae that had, in fact, become pupae. Therefore, their share is subtracted (the last term). The second term is the consumption by larvae that hatch in the tth time interval.

The Plant

Two components of the plant are considered—the stem and the leaves.[8] The leaf mass, m_t, measured in grams, grows as a function of both leaf mass and root reserves. The algorithm presented by Gutierrez et al. was too complex to utilize; hence, the following form is used:

$$(5)\quad m_{t+1} = m_t\,(1 + \eta_1) + \eta_2 - v_t; \quad t_o + b \le t \le t_f - 1;$$

m_{t_o+b} is given. This captures the essence of the simulation model. The plant grows from current photo-synthetic production, which is a feedback function, $m_t(1 + \eta_1)$, and from root reserves, η_2, which in reality fluctuate with time (i.e., if the plant is completely defoliated, $m_t = 0$, and it can regenerate by η_2). The stem mass is not directly damaged by the pest to any great extent but is indirectly affected by the leaf damage.

Using field data by Christiansen and Gutierrez, it has been possible to estimate the stem mass, S, at time t_f as a positively related function of the leaf mass in that time, $S = h(M)$, where $M = m_{t_f}$ is the leaf mass at cropping time.

Interseasonal Pest Dynamics

The infestation rate, θ, is a parameter that is determined by the following factors: total number of pests that aestivated from all the fields in the region, weather and ecological conditions during aestivation time, and the location of the field.[9]

Since pesticide applications do not appear to affect the pupae, the number of young adults per acre, A, that leave a given field can be approximated by $A = 43{,}560 \sum_t Z_t$.[10] Assuming that there are J acres in the region, then for a given acre i at a given season n, the infestation parameter, $\theta_{i,n}$, is given by the function

$$(6)\qquad \theta_{i,n+1} = g^*_i\left(\sum_{j=1}^{J} A_{j,n}\right),$$

where $A_{j,n}$ is the total number of adults that leave the jth acre for aestivation during the nth season.

The Economic Problem

The economic problem is to find the pest control policy that will maximize net gains. In the following analysis, a distinction is made between gains collected by each decisionmaker separately and those considered from the societal viewpoint.

The Private Viewpoint

The crop of alfalfa hay is measured by the weight of stems and leaves. However, its price is not fixed (even to the competitive farmer) and positively depends on the quality of the hay. A measure of the quality is the leaf-stem ratio. Let $p_m(M)$ denote the price of the hay; then

$$(7)\quad p_m \equiv g\left(\frac{M}{S}\right) \equiv g\left(\frac{M}{h(M)}\right) \equiv p_m(M),$$

where S is stem weight at cropping time and $h(M)$ is a function relating stems to leaves $[h'(M) > 0]$.[11] It is further assumed that p_m is continuous with $0 \le [p'_m(M) = g'(\cdot)\ (h -$

[8] The horizon is one season (until the first cutting of the hay). The effect of leaf damage on root reserve depletion was considered originally since this factor may affect second and third croppings. However, observations in commercial fields show a negligible effect of the pest either within the horizon or on the subsequent croppings and no effect later on.

[9] A region is defined here as the area comprising all fields such that an aestivating pest from one field could possibly reach any other field in the region during the following season. Although the weevil has a tendency to aggregate during the aestivation period, it is believed to be highly mobile during the phases of migration to and from the fields. Experience with other insects of the same biological order suggests that the weevil may cover considerable distances at the time of migration. It is thus very likely that weevils originating from any one field will eventually arrive at other fields in the region. One should recall that most alfalfa growing farms in California are less than 200 acres in size, which is considered well within the migration range of the weevil.

[10] Since biological data were given per square foot and economic functions are on a per acre basis, the conversion factor (43,560) was used when necessary.

[11] Prime denotes first derivative, and double prime denotes second derivative. When functions of two or more variables are defined, their partial derivative will be denoted by subscripts of the variable with respect to which derivative is taken.

$h'm)/h^2] < \infty$, namely, that the price is nonnegatively related to leaf mass, M. The revenue of a single farmer is thus

$$(8) \qquad R(M) = p_m(M)[M + h(M)],$$

and, under the above assumptions, $R'(M) \geq 0$. The sign of $R''(M)$ depends on the signs and magnitudes of $g''(M)$ and $h''(M)$; but if both equal 0, then $R''(M) \geq 0$.

The farmers are assumed to be pricetakers in the pesticide market, and a one-season objective function is

$$(9) \qquad \Pi^{(1)} = R(M) - p_x \sum_{t_0}^{t_f} x_t,$$

where p_x is the fixed pesticide price.[12] The first problem is a single-season decision: maximize equation (9) subject to the equations (1), (4), (5), and (8) and the constraint that all variables in the system be nonnegative. It is assumed that no single farmer is large enough to affect the regional pest dynamics significantly and therefore would not take it into consideration in his pest control policy.

The objective defined by equation (9) fails to consider the possibility that secondary pests are likely to develop following pesticide applications because of the disturbed ecological relationships in the field. In alfalfa, it has been observed that, when pesticides are applied late in the season against the major pest—the weevil, secondary pest outbreaks may occur, requiring the use of additional control measures in subsequent time periods of the season (Summers and Cothran 1972a). As the secondary outbreaks occur beyond the specific horizon adopted in this model, they are taken into account by a set of extra charges on pesticide applications that occur at later time periods within the model's horizon. The penalties reflect the cost of additional controls that will result later from the current use of pesticides. Alternatively, these charges may be considered as a reflection of yield reduction in later croppings in the season resulting from secondary pest outbreaks. The objective function is then

$$(10) \quad \Pi^{(2)}(x, \theta) = R(M) - \sum_t (p_x + \mu_t)x_t,$$

where μ_t is the appropriate charge that accounts for the damage of the secondary pest. A discussion of μ_t is presented in the appendix.

The Societal Viewpoint

The objective function defined by equation (10) overlooks several major aspects of the pest-control problem. Among them are the aspects of pest resistance, interseasonal pest dynamics, and a few types of external effects of pesticide applications on the environment. The present model, however, focuses only on the interseasonal relationships and assumes that no other external effects exist.

Assuming pests are identically distributed over the region, a central decision agency would maximize the present value of the net returns per acre:

$$(11) \qquad \Pi^{(3)} = \max_{\{x_n\}} \sum_{n=0}^{N} \beta^n \, \Pi^{(2)}(x_n, \theta_n),$$

where x_n = vector $(x_{1n}, x_{2n}, \ldots, x_{tn}, \ldots, x_{t_f n})$ of controls at the nth season, $\beta^n = 1/(1 + r)^n$ = discount factor using the appropriate discount rate, r, and N = planning horizon. This maximization is subject to the same constraints as before, equations (1), (4), (5), and (8), repeated for each season. An additional set of constraints accounts for the interseasonal relationship

$$(12) \quad \theta_{n+1} = g^*\left(\sum_j^J A_{jn}\right) = g^*(JA_n) = g(A_n) = \gamma \cdot A(x_n, \theta_n); \quad n = 0, 1, \ldots, N,$$

where A_n is the number of adult pests leaving for aestivation per acre during the nth season, γ is the parameter of proportion between adults leaving per acre at the nth season and the rate of infestation in season $n + 1$, and the initial infestation rate, θ_0, is a given parameter. This equation is similar to equation (6) but is simplified due to the assumption of identical pest distribution and the linearity of the function $g(\cdot)$.

Private Vis-à-Vis Societal Policies

Private decision rules are obtained by a maximization of the problem for one season. Define $G(x, \theta)$ as the Lagrangian corresponding to $\Pi^{(2)}(x, \theta)$ and the constraints (1), (4), (5), and (8). The private decision rules obtained by the maximization of $G(\cdot)$ are

[12] This objective function ignores the possibility of fixed application costs, which will be discussed later when the computational results are analyzed.

(13) $$G_x(x, \theta) = 0.$$

Societal decision rules are obtained by

(14) $$\max_{\{x_n\}} \sum_{n=0}^{N} \beta^n \{G(x_n, \theta_n) - \beta\lambda_{n+1}[\gamma A(x_n, \theta_n) - \theta_{n+1}]\},$$

where λ_{n+1} is the Lagrangian multiplier associated with the constraint (12).

Burt and Cummings describe a general optimization model for natural resource management. Necessary conditions for a solution to this problem include

(15) $$G_{x_n} - \lambda_{n+1}\beta\gamma A_{x_n} = 0, \quad n = 0, 1, \ldots, N,$$

and

(16) $$\lambda_n - \lambda_{n+1}\beta\gamma A_{\theta_n} = -G_{\theta_n}, \quad n = 0, 1, \ldots, N.$$

The expression $\lambda_{n+1}\ \beta\gamma\ A_{x_n}$ reflects the future gains (by reducing θ) of a marginal increase in the control at the nth period; it is appropriate to denote it as a (negative) "user cost" (Scott).

If a solution to equation (14) were possible, λ_n could be found, and a path of optimal shadow prices over time would yield the optimal policy. The curse of dimensionality, however, impedes such a solution.[13] One approach adopted here is to derive the societal steady-state solution by means of solving iteratively a sequence of one-season problems.

At the steady state, if it exists, for sufficiently large n, $\theta_n = \theta_{n+1} = \theta$, and $\lambda_n = \lambda_{n+1} = \lambda$. For this case, equations (15) and (16) become

(17) $$G_x - \lambda\beta\gamma A_x = 0,$$

and since $A_\theta = 1/\gamma$,

(18) $$-G_\theta = (1 - \beta)\lambda.$$

In the following, it is shown how the steady-state infestation rate, θ, and its corresponding shadow price, λ^*, could be found and the implications for pest-control policies analyzed. Define a modified one-season problem,

(19) $$\max \mathscr{L} = G(x, \theta) - P \cdot A(x, \theta),$$

where P is now an arbitrary parameter. The necessary condition is

(20) $$G_x - PA_x = 0.$$

Comparison of equations (17) and (20) indicates that, if one could find a value of P such that $P = \lambda^*\beta\gamma$, this would represent at steady state the marginal cost to society of pests leaving for aestivation and, therefore, yield the optimal steady-state solution. The procedure is as follows. Equation (19) is solved for some arbitrary P and a given θ_0. Using equation (12), θ_1 is obtained and the solution procedure is carried out iteratively. For any arbitrary P, the solution for the modified problem, equation (19), yields a value for $\mathscr{L}_\theta = G_\theta - PA_\theta$. In the above iterative procedure, $\{\theta_n\}$ converges to a steady state $\theta^*(P)$; insert $P = \gamma\lambda\beta$ and use equation (18). Then

(21) $$P = -\beta\gamma\mathscr{L}_\theta = -\frac{\gamma\mathscr{L}_\theta}{1 + r}.$$

This equation gives the optimal steady-state value, P^*, as a function of the discount rate, r.

Analysis of Results

The results presented here for the pest-control policies in alfalfa are based on the data and estimation procedures explained in the appendix. The analysis of the results focuses on the comparison of optimal pest-control policies obtained from private and societal decision rules and currently used practices. The solutions have been obtained by a nonlinear programming computer program written by Abadie (Generalized Reduced Gradient Algorithm), which was executed on a CDC 6400 computer (Abadie and Guigou).

Solution for a Single Decisionmaker

A single farmer is concerned only with pest control within a single season. He should, however, be aware of outbreaks of secondary pests and consider them in his decisions. Therefore, the problem of maximizing $\Pi^{(2)}$ (equation (10)) is regarded as the relevant problem for the single farmer.

Application of a total of twenty-eight ounces per acre of the pesticides is optimal in this case where applications are made in time

[13] The complexity of the biological relations has been greatly simplified in the current model, but the size of a single-season problem for the case study actually solved could not be reduced below 50 variables and 40 constraints, with most of the constraints nonlinear.

Table 1. Current and Optimal Private Pesticide Application

Type of Solution	Application Time (60 D°) 1	2	3	4	5	6	7	8	9–21	Total Amount Applied	Net Pest Control Revenue Per Acre
	(Oz./Acre)										
Current practices	0	0	0	0	0	0	0	16–32	0	16–32	\$88–\$101
Unrestricted private optimal solutions	1.5	9.8	4.3	12.6	0	0	0	0	0	28.2	\$116.84

periods 1 through 4 only (table 1). The optimal timing of pest-control applications is in time periods up to and including the time of peak adult population (cf. figure 1). This is prior to the last frost, at which time the seasonal regrowth of the alfalfa starts. Furthermore, since the frosts destroy the larvae, pesticide applications prior to the last frost are directed primarily against the adult pest. This result is strengthened by the fact that pesticides are more efficient in the control of larvae than of the adult pest (e.g., given the parameters estimated here for pesticide application of sixteen ounces, about 20% of the adults compared with 4% of the larvae will survive; see appendix). Pesticide applications made early in the season reduce not only adult numbers but also the future population of eggs and larvae. The common practice at present is to apply pesticide only when large larvae are found in the field, which is approximately three time periods after the last frost. The amount of pesticide applied varies greatly in practice, ranging from less than sixteen ounces to thirty-two ounces per acre depending upon the timing of the first application and on the actual damage throughout the season. Comparison of the net pest-control gains of private optimal policy with current practices (table 1) clearly indicates the advantage of the former. The most important practical conclusion of these results is, however, the indicated shift in the timing of pesticide applications to a new control target (i.e., the adult pest rather than the larvae).

The results presented above are based on the model assumptions that include time-dependent charges on applications. These charges impose heavier costs on applications that occur later in the season. Compared with the basic pesticide cost of forty cents per ounce, the charges actually used to obtain the above results are zero up to (and including) the fifth time period but increase linearly thereafter, reaching \$1 per ounce in the tenth period and remaining constant at that level (see explanation in the appendix). Since the timing of applications is a major point of difference between the results obtained here and current practices, it is interesting to examine the sensitivity of the control policy to the extra charges, μ_t, imposed on pesticides. The solution to the problem with all extra charges set at the zero level is found to be identical with the solution of the problem incorporating the charges. It is thus concluded that, even without consideration of secondary outbreaks, spraying should take place before the last frost and be directed against the adult pest.

This last result is not changed when the effects of fixed application cost are considered. Since fixed costs could not be directly treated in our computer program, an indirect approach was used. Solutions were obtained to the problem under constraints imposing one or two treatments in specific time periods. Comparing the values of the objective function, it was observed that one treatment in the third period or two treatments in the second and fourth periods were superior to all other single or double treatments, respectively (table 2). The difference between the best two-treatment and one-treatment objective functions is \$2.70 per acre. Thus, if the fixed application cost is more than \$2.70, then a single treatment (in the third period) is preferred. The unrestricted solution calls for four treatments; however, its objective function is only ten cents per acre higher than the two-treatment solution. In any case, treatments are suggested early in the season only.[14]

Aspects of a Societal Solution

The previous results took no account of the future potential damage embodied in pests that currently leave for aestivation. As noted be-

[14] Not all possible 190 combinations of two treatments were calculated, since the pattern of results allowed us to discard most of the combinations a priori.

Table 2. Policies for Spraying When Application is Imposed in Specific Periods

Periods of Application	Value of Objective Function ($)	Amount of Pesticide in Respective Periods (oz./acre)
One treatment		
1	109.6	23.0
2	112.8	24.0
3	113.9	24.4
4	113.5	24.2
5	110.5	23.3
6	102.8	17.9
7	97.6	13.6
8	94.5	10.3
Two-treatment combination		
1–3	114.8	8.2–18.1
1–4	116.1	11.6–16.9
1–5	114.9	13.9–15.0
1–7	109.6	22.6– 0.5
2–4	116.7	13.4–14.6
2–6	113.7	20.6– 5.5
3–4	115.7	13.8–12.6
3–6	114.0	23.1–16.5
4–8	114.3	22.9– 2.7

Note: These results are for the individual farmer problem and assume that no spraying occurs in all other time periods.

fore, the sequence of shadow prices and the optimal policy cannot be practically calculated. One way to account for the dynamic effects is to impose various values for the shadow price, λ, and to study the sensitivity of the solutions. Another approach used here is to calculate the optimal solution at steady state by iterative procedures.

For the first method three alternative values for P are used, and the results are presented in table 3. As in the solution for a single farmer's problem, for all shadow prices, the bulk of the spraying takes place early in the season prior to the last frost. However, larger values of P imply that both a greater total dosage and an additional application in the eighth period are required, even though the latter application is relatively small. From an examination of the suggested amount of pesticides applied (using different values of P), it appears that P = 0.23¢ per 1,000 pests is a reasonable upper limit for P and, if this is the case, no pesticides should be applied after the fourth period.

Using the results in table 3 as an indication of the effects of various values of shadow prices is one way to examine the effect of fixed application costs on spraying policy. The procedure used is similar to the one employed when fixed application costs were introduced for the single farmer's problem. In this case only a few relevant combinations were checked (P = 0.23¢ and P = 2.3¢ per 1,000 pests). Table 4 brings together those results but only for the time combinations that yielded the highest values of the objective function. For P = 2.3¢ the eighth period application should be eliminated if the fixed application cost is more than $2.75. The amount of pesticides is essen-

Table 3. Sensitivity of Solutions to Arbitrary Shadow Prices Imposed on the Modified One-Season Problem

	Solution 1	Solution 2	Solution 3	Solution 4
P (¢/1,000 pests)	0	0.23	2.3	9.2
Objective function ($/acre)	116.84	113.01	100.79	90.20
Pesticide application (oz./acre)				
Spraying period				
1	1.49	4.16	8.74	9.55
2	9.78	10.42	11.75	12.13
3	4.30	5.23	7.26	7.69
4	12.62	16.59	27.80	37.87
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	3.39	9.01
9–21	0	0	0	0
Pest leaving field per square foot (A/43,560)	50.70	30.25	7.094	2.006
Rate of infestation (θ_{n+1}) under the assumption				
$\gamma = 0.003846$	0.1950	0.1163	0.0273	0.0077
$\gamma = 0.001538$	0.0780	0.0465	0.0109	0.0031

Note: This analysis assumes $\theta_n = 0.174$; $\mu_t = 0$ for $t \leq 5$; $\mu_t = -1 + 0.2t$ for $t = 6, 7, \ldots, 10$; and $\mu_t = 1.00$ for $t \geq 10$.

Table 4. Optimal Policies for Specific Shadow Prices When Application Is Constrained to Specific Time Periods

	Unconstrained Solution[a]	Constrained Solution[a]		Unconstrained Solution[b]	Constrained Solution[b]
Objective function ($/acre)	100.79	97.26	100.01	113.01	112.71
Pesticide application (oz./acre)					
Spraying period					
1	8.7	0	0	4.2	0
2	11.8	28.3	19.6	10.4	16.9
3	7.3	0	0	5.2	0
4	27.8	31.1	31.2	16.6	19.0
5	0	0	0	0	0
6	0	0	0	0	0
7	0	0	0	0	0
8	3.4	0	5.9	0	0
9–21	0	0	0	0	0
Number of aestivating pests (A) per square foot	7.10	11.82	7.23	30.25	32.32

[a] $P = 2.3$ ¢/1,000 pests.
[b] $P = 0.23$.

tially not affected by fixed cost (for both prices), and the same timing of application is generally retained.

Comparing the societal with the private solution, it is concluded that the inclusion of future damage results in heavier spraying and smaller numbers of pests leaving for aestivation. This conclusion is maintained with or without fixed application costs. As will be demonstrated below, pesticide use at steady state is only slightly higher than the solution suggested by the last row in table 1 (private solution) but is much lower than the one suggested by tables 3 and 4. This may suggest that, along the unknown optimal path for the societal solution, pesticide use should be high initially and then decline as it approaches the steady state. It should be noted that this policy would be the optimal one only if resistance to pesticides is absent and is not expected to develop. The problem may be further complicated by the recognition of other externalities.

The steady-state solution is based on successive iterative solutions of the modified one-season problem, and the optimal steady-state shadow price is obtained as a function of the interest rate. The procedure is based on the results obtained in equation (21) in the following way. For some (arbitrarily fixed) value of γP (using $\gamma = 0.0038$), the problem defined by equation (19) is solved iteratively, where in each iteration θ_{n+1} is determined by the value of A_n using equation (12). $|\theta_{n+1} - \theta_n| < \epsilon$ has been used as the criterion for terminating the iterative process and determining $\theta^*(P)$ in the steady-state value. In the computation, $\epsilon = .01\theta_n$ has been used. Equation (21) is then used to determine the discount rate r for which the above values of P and $\theta^*(P)$ would be optimal. The results form a mapping from r into $[P, \theta^*(P)]$ (figure 2). $P(r)$ is negatively sloped function that goes to 0 as r goes to ∞ and reaches a finite value when $r = 0$. This mapping gives a target for pest-control policy in the sense that, given a discount rate of, say, 9%, an optimal societal steady-state rate of infestation should be about 0.02, and the corresponding shadow price P is 2.3¢ per 1,000 pests. It is important to note that, once a steady state $\theta^*(r)$ is obtained, the level of pesticide application is about the same for all values of P that have been tried—around thirty-two ounces per acre—compared with the private optimum of twenty-eight ounces per acre. The timing for pesticide applications is, however, similar to the solution for the former (private) problem. Unlike the results in table 3, the eighth period application is eliminated in the steady-state solution. The impact of fixed application costs is as before; it reduces the number of applications without changing the general timing of the applications and their total amount.[15]

[15] In order to save space, these results are not presented.

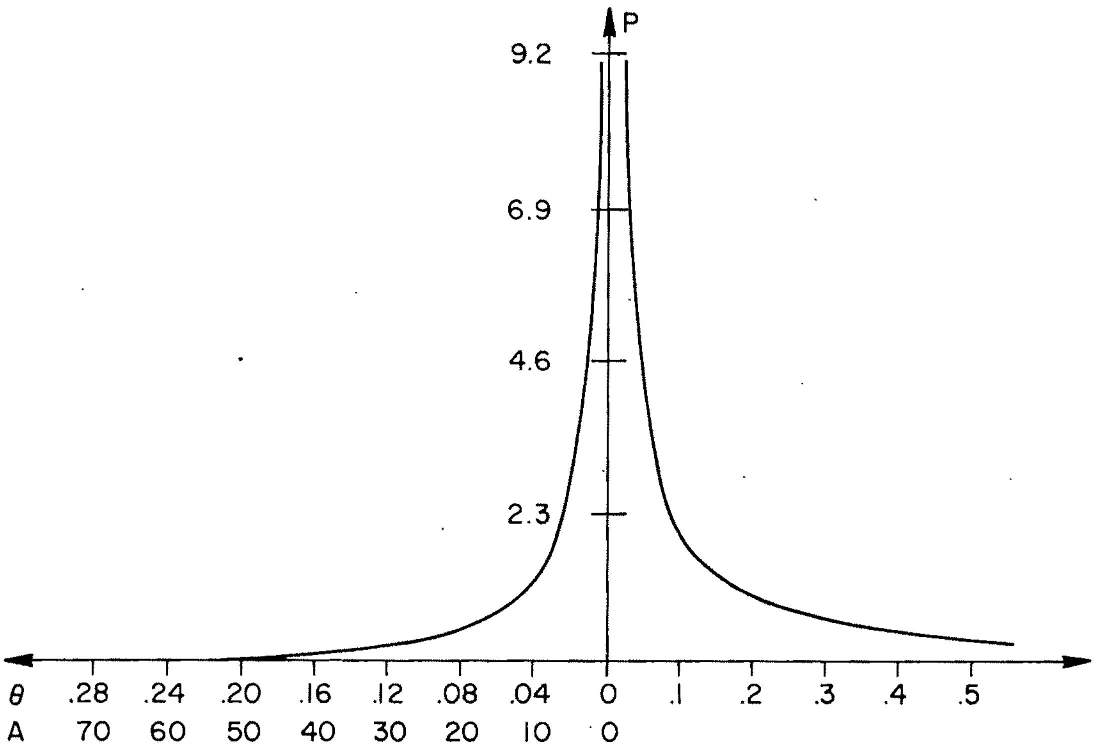

Figure 2. Optimal steady-state relationships between discount rate, *r*, penalty on pests leaving the field, *P*, in cents per 1,000 pests, and the number of pests, *A*, leaving the field (infestation rate, *θ*, is a fixed proportion of the number of pests leaving the field)

Conclusion, Policy Implications and Extensions

The following points summarize the major results and offer some suggestions for future research. The major discrepancy between the results obtained here and current practices involves the timing of pesticide application. The results obtained here indicate the advantage in applying pesticide prior to the growth season. Specifically, application is centered around the time period in which the number of adult pests peaches its peak. Within a given season, the individual farmer is not affected by his neighbors' decisions; however, in the long run each farmer is affected by the cumulative effects of the individual decisions. In this case the pest constitutes a "common property resource," and a nonregulated market would not yield the optimal solution. The optimal societal solution could be implemented by an information agency that would enhance mutual cooperation between farmers (e.g., the Extension Service). It has been shown that a shadow price of 2.3¢ per 1,000 adults emerging per acre is the steady-state social cost. This corresponds to a discount rate of approximately 9%. Higher discount rates imply lower social cost and higher steady-state infestation rates.

Future research is clearly desirable to ascertain many of the functions and to obtain better estimates for some of the parameters before this solution is to be applied. These results are, therefore, important in indicating the direction for better pest-control policies and in pointing out directions for future research regarding critical parameters and functional relations upon which the solution rests. Further work is also needed to obtain the optimal policy path over time. This model can be extended by using the interseasonal results obtained here in a dynamic programming framework to find a multiseasonal optimal policy. One important component that has not been incorporated in this model is pest resistance to chemical pesticides. However, this possibility raises the question whether a policy that leads to heavy suppression of the pest by chemical pesticides is desirable, as it may bring on a speedy development of resistance.

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Appendix

Data Sources and Estimation Procedures

The appendix presents the data sources, estimation, and derivation procedures of the various parameters in the model as applied to the control of the Egyptian alfalfa weevil in California.

The Rate of Infestation, θ

For a one-season problem, the pest infestation rate θ is a constant. This has been estimated at 0.174 by Gutierrez et al. from early season field counts. The interseasonal relationship $\theta_n = \gamma A_{n-1}$ is an approximation adopted here. The estimate of γ (0.0038) is based on the observation that, using current practices, the average adult peak is about 0.05 of the number of adults that leave the field, and adult peak time occurs thirteen time periods after the arrival of the first adults from aestivation.

The Kill Function

The kill function is taken from a field pesticide experiment by Cothran and Christiansen. Pesticides were applied against the adult population early in the season, and the effect measured the number of offspring produced by the survivors. This is a reasonable estimate of survivorship because the adults remain in a very limited area of the field, and the subsequent count of larvae accurately reflects their survivorship via fecundity when compared to an untreated control. The resultant survivorship curve was estimated from their field data by the curve e^{-ax} with

$\alpha = 0.1$ and is representative of the effects of Carbofuran and Heptachlor on adult Egyptian alfalfa weevil populations ($R^2 = 0.89$ and the student t-value was 16.7). Pesticide applications are more effective against larvae, and $\delta = 0.2$ (equations (4) and (5)) has been estimated from Summers and Cothran (1972b) by comparing equivalent application rates on estimated larval survivorship and assuming that the kill function has the same form.

Oviposition Rates, E_t

The maximum oviposition rate is 2.2 eggs per female per D° (= 132 eggs per one time interval). Laboratory feeding experiments and field observations indicate that the beetles fail to feed during periods of adverse weather conditions (i.e., too cold, rainy, etc.) and, as a result, fecundity declines. Gutierrez et al. describe these experiments and formulate equations to estimate weather effects on egg laying. These occur annually, although the pattern may vary. Hence, a pattern and magnitude of these effects for a typical year were estimated and included in the model. Fecundity is also age dependent and was estimated from laboratory experiments. Field and laboratory data indicate that adults entering the field must feed approximately 400 D° before they can oviposit. Incorporating all of these effects resulted in the following oviposition rates per adult: $\{E_t\} = \{1.8, 9.6, 14.2, 11.7, 19.2, 27.0, 33.3, 37.8, 42.5, 41.9, 55.8, 60.9, 66.0, 32.2\}$, for $t = 1, 2, \ldots, 14$.

Larval Consumption Rate

Koehler and Pimentel estimated leaf consumption rates for a related species of alfalfa weevil. Because the species are taxonomically close and of approximately the same size, it was felt that this was a reasonable value to use in the model. A geometric function was fitted to their data.

$$\rho \sum_{t=1}^{6} (1 + a)^{t-1} = 7.5,$$

where the total consumption of a larva during its lifetime (six periods) is 7.5 milligrams of leaf tissue, $1 + a$ (= 2.3) is the geometric rate of increase of the function per 60 D°, and ρ (= 0.0043 grams) is the consumption of a larva during its first 60 D°.

The Plant

The parameters η_1 and η_2 of equation (5) were estimated as follows. Using a simulation model of the plant, eight successive observations of m_t were obtained for the hypothetical situation of zero pest population (i.e., $V_t = 0$). As the simulation model's time period is approximately twice as long as the present model, the following equation was estimated:

$$m_{t+2} = (1 + \eta_1)^2 m_t + [2 + \eta_1]\,\eta_2.$$

This equation is easily derived from equation (5). The estimates were

$$(1 + \eta_1)^2 = \underset{(3.5)}{1.1256}$$

and

$$\eta_2\,[2 + \eta_1] = \underset{(16.1)}{1.0914},$$

where the figures in parentheses denote student t-values. The R^2 of the regression was 0.977. On the basis of these estimates, η_1 and η_2 were calculated. Total stem weight, S, (grams per square foot) is linearly related to the amount of leaf tissue at harvest, M, by the function $S = 9 + (15/16)\,M$, $0 \le M \le 16$, grams per square foot. All field estimates were estimated on a square foot basis, but economic values are scaled to dollars per acre.

Alfalfa Quality and Price

The quality of alfalfa hay can be measured by its leaf-to-stem ratio. The price P_m per gram of alfalfa is strongly influenced by this ratio. The price for alfalfa which has been used here is \$80 per ton for maximum quality and \$5 per ton if completely defoliated. By linear interpolation, $P_m = (0.55 + 0.516\,M)10^{-5}$ in dollars per gram. The revenue, R, is then $R = (S + M)\,P_m = 2.16 + 2.49\,M + 0.435\,M^2$ in dollars per acre.

Pesticide Cost

Pesticide costs (forty cents per ounce) are reasonable estimates for alfalfa production in northern California during the 1972–74 period and were obtained by consultation with W. R. Cothren and R. W. Bushing, University of California, Davis. This is the current cost estimate for Furdan, the most commonly used pesticide applied for the control of the Egyptian alfalfa weevil. Exact estimates for the cost of secondary pest outbreaks, μ_t, of aphids, lepidopterous, and other pests are unavailable and have been estimated from experience. It is commonly observed by entomologists that applications of pesticides on alfalfa (and other crops, e.g., cotton) to control pests result in additional pesticide use to control the induced secondary pests. Pesticides applied late in the spring disrupt the ecological relationships more than pesticides applied during the winter period when most of the nontarget species are dormant (Summers and Cothren 1972b). This is reflected as an increasing linear charge of 0 from the last frost (the fifth period) to a maximum of \$1 at the tenth period and thereafter; i.e., $\{\mu_5, \mu_6, \mu_7, \mu_8, \mu_9, \mu_{10}, \mu_{11}, \ldots\} = \{0, 0.20, 0.40, 0.60, 0.80, 1.00, 1.00, \ldots,\}$.

An Analysis of Alternative Financing Strategies and Equity Retirement Plans for Farm Supply Cooperatives

Wilmer A. Dahl and W. D. Dobson

Cooperatives are experiencing pressures to increase cash patronage refunds, reduce financing costs, and retire equity capital of farmer-members who die, retire, or leave the cooperative's service area. Farm supply cooperatives could increase cash patronage refunds by over 90 % and reduce financing costs by 6% to 9% by employing moderately different capital acquisition practices. Solvency of the cooperatives could be reduced substantially if mandatory equity retirement plans being considered by legislators and courts were adopted.

Key words: cooperatives, equity retirement, financing costs, linear programming, patronage refunds.

U.S. agricultural cooperatives rely heavily on revolving fund capital for financing growth and operations.[1] There are advantages to this financing practice. Problems with debt service and risk normally are small when this type of equity capital is the primary capital source. The revolving fund also provides a convenient way for cooperatives to raise capital. And, in theory, revolving fund financing keeps ownership of the cooperative in the hands of present members and financial contributions of members proportional to the use they make of the cooperative.

However, as the following studies indicate, this financing practice also has created problems. Griffin; Hulbert, Griffin, and Gardner; Fenwick; and Snider and Koller suggest that capital costs of agricultural cooperatives are higher than necessary because the firms use too much revolving fund (equity) capital and too little debt. Snider and Koller report that some cooperatives place a zero cost on revolving fund capital, which causes them to underestimate the overall cost of capital and overinvest in facilities.[2] Tubbs indicates that for aggressive farmers who look to expand their farm businesses capital contributions to cooperatives are frequently made at a large and often unrecognized sacrifice to the contributing farm firm (p. 6). Tubbs also shows that some farmers in higher income tax brackets actually lose money if they accept a cooperative's patronage refund when it consists of the 20% minimum in cash and an 80% book credit.[3] This occurs because the farmer-member pays income taxes on both the cash portion and book credit immediately and may not receive any cash payment for the 80% book credit for many years under the revolving plan. Therefore the farmer may find that the discounted present value of the cash pa-

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[1] Revolving fund capital is obtained from capital deductions from members and/or margins realized from the cooperative's operations. Under a revolving plan, earnings or capital deductions obtained during the current year are used to retire the oldest outstanding revolving fund capital furnished to an association by farmer-members of earlier years.

[2] Snider and Koller found that certain Minnesota milk cooperatives underestimated their weighted average capital costs by over four percentage points when revolving fund capital was priced at a zero level. Results of this study showed that the average Wisconsin farm supply cooperative would underestimate its weighted average cost of capital by about two percentage points if a zero cost was attached to its revolving fund capital.

[3] The "20% minimum in cash" is a requirement of the Revenue Act of 1962. Under this Act, cooperatives must pay at least 20% of their member patronage refunds in cash if they wish to deduct total member patronage refunds from gross income when computing federal income tax obligations.

tronage refund and book credit is less than his immediate tax obligation on the total patronage refund.

Cook reports that many U.S. agricultural cooperatives have failed to develop systematic plans for retiring the equity capital of members who die, retire, or leave the community. Cooperative management is experiencing increasing pressure from members and legislators to develop such plans. According to Cook, bills have been introduced and/or court actions instituted in eleven states to require agricultural cooperatives to systematically retire equity capital of members who are no longer actively associated with the cooperative.

The criticisms contained in the above studies call for agricultural cooperatives to reduce financing costs, increase cash patronage refunds, lessen financial sacrifices of members, reduce the length of revolving periods, and retire equity capital of members who die, retire, or leave the cooperative's trade area. However, it is difficult to draw clear prescriptions from the studies. The studies fail to indicate, for example, what constitutes an optimal financial structure for agricultural cooperatives and whether cooperatives would realize substantial cost savings if they achieved optimal financial structures. Also, it is not clear whether it would be feasible for cooperatives to adopt financing practices that would reduce financing costs substantially and remedy other financial management problems identified in the studies.

Objectives of Study

This study examined the optimal financial structure and feasibility questions. Specific objectives of the study were the following: (*a*) to determine the optimal financial structure (i.e., least-cost combination of revolving fund capital, short- and long-term debt, common stock, preferred stock, etc.) for representative Wisconsin local farm supply cooperatives under nine different financing plans for 1966 through 1974; (*b*) to determine how much financing costs of the cooperatives would have been reduced if they had followed the prescriptions represented by the optimal structures (the different financing plans considered involve five- and ten-year revolving plans and cash patronage refunds of 20%, 40%, 60%, 80%, and 100% of total patronage refunds); (*c*) to examine liquidity and solvency of the cooperatives under each of the different financing plans to determine which of the plans would be most feasible to adopt; and (*d*) to examine solvency of the cooperatives under plans that require them to retire equity capital of members who die, retire, or leave the areas served by the cooperative.

This study was based on data for all 189 Wisconsin farm supply cooperatives. The cooperatives that provided the data serve a cross-section of dairy, beef, hog, and cash grain farmers. Therefore, the results may be applicable to farm supply cooperatives elsewhere in the United States.

Linear Programming Models Used in Study

Recursive linear programming (LP) models were employed in the study to determine optimal financial structures for the Wisconsin local farm supply cooperatives. The LP models used in the analyses are recursive in the sense that constraints for a given year depend upon the nature of the optimal solution for the previous year. In the study, base period figures for 1966 and figures from the optimal solutions for seven subsequent years were employed in the models to compute minimum cost financial structures for representative Wisconsin farm supply cooperatives for each year of the 1966–74 period.

Capital source variables included in the objective function of the models were as follows: C^{ps} (preferred stock), C^{cs} (common stock), C^{bct} (Bank for Cooperatives term loans), C^{bcs} (Bank for Cooperatives seasonal loans), C^{ci} (certificates of indebtedness), C^{ost} (other source term loans),[4] C^{oss} (other source seasonal loans), C^{as} (allocated savings or revolving fund capital), and C^{us} (unallocated savings). The minimum cost financial mix was selected by the LP models from the above source variables subject to the following constraints. Total short-term debt, long-term debt, plus equity capital acquired each year must equal capital needed each year. Term loans acquired from the Bank for Cooperatives and other sources must be repaid to lenders with interest in eight years; term loans acquired from commercial banks must be fully repaid with interest to lenders in ten years. Federal income taxes at appropriate normal and surtax

[4] Other source debt consists primarily of loans made to local cooperatives by affiliates of regional cooperatives.

rates must be paid on unallocated reserves of cooperatives. Preferred and common stock issued must not exceed amounts authorized in bylaws of cooperatives. Also, annual increases in sales of preferred stock, common stock, and certificates of indebtedness must not exceed upper bounds based on historical sales figures. Annual increases permitted under the models averaged 7.1%, 2.6%, and 14.2%, respectively, for common stock, preferred stock, and certificates of indebtedness. Net savings generated each year by a cooperative must be distributed to four accounts—stock dividends, unallocated savings (unallocated reserves), federal income taxes, and total patronage refund (TPR). Under the models, TPR was further subdivided into cash patronage refunds (CPR) and allocated savings (AS) or book credits. The allocated savings were revolved back to farmer-members at future dates under the revolving plans incorporated in the models.

Minimum cash patronage refunds expressed as a percentage of total patronage refund and length of revolving period incorporated into constraints were as specified in table 1 for the different models. The model designations appearing in table 1 serve as a key for identifying solutions in subsequent discussions. Thus, model II will refer to an LP solution in which a cooperative pays a 40% cash patronage refund under a five-year revolving plan.

Table 1. Cash Patronage Refunds and Length of Revolving Period for LP Models Employed in Study

Model	CPR as Percentage of TRP	Length of Revolving Period (years)
I	20	Not computed[a]
II	40	5
III	60	5
IV	80	5
V	100	5
VI	40	10
VII	60	10
VIII	80	10
IX	100	10

[a] Model I calculates least-cost financial structures under the restriction that allocated savings revolved back to members must equal averages of the actual amounts revolved back to members. Figures on the actual amount of capital revolved back to members were available from the financial statements of the cooperatives. But, typically, it was impossible to determine from these financial statements what length of revolving period the cooperatives employed for revolving back the allocated savings. Therefore, it was not possible to compute an average length of revolving period for the model I solutions.

Model I includes constraints that parallel closely the actual restrictions that managers and boards of directors observe in running the cooperatives. Thus, this model required that 20% of total patronage refunds be made to farmer-members in cash, annual cash payments from the revolving fund be equal to actual amounts revolved back to farmer-members, debt-equity ratios be 1.0 or less, and the current ratios equal or exceed 1.7. Debt-equity and current ratio constraints were omitted from models II through IX, since it was desired to see how much the solvency and liquidity ratios would vary under a full range of different financing plans. Moreover, conflicts among restrictions made it impossible to obtain mathematical solutions when liquidity and solvency constraints similar to those of model I were included in models requiring the highest cash patronage refunds.

Under models II through V (five-year revolving plan models), savings allocated to members in 1966, 1967, 1968, and 1969 were revolved back to them during 1971, 1972, 1973, and 1974, respectively. No capital was revolved back to farmer-members during 1966 through 1974 under models VI through IX, since the first payments under these ten-year revolving plan models would not have been due until 1975.

The LP analyses were based on figures for all 189 local supply cooperatives in Wisconsin. These local cooperatives sold feed, seed, fertilizer, hardware items, bulk gasoline, and petroleum products. The cooperatives were grouped into the size categories indicated in table 2 before making the analyses. LP results obtained for representative (average) firms from each size group were multiplied by appropriate expansion factors to draw inferences about the population of cooperatives.

Figures on sources and uses of funds required for the LP studies were obtained from various sources. Required balance sheet and

Table 2. Size Categories Represented by Typical Cooperatives Employed in LP Study

Group	Annual Sales	Number of Cooperatives in Group
1	Less than $500,000	47
2	$500,000 to $1,000,000	74
3	$1,000,000 to $1,500,000	35
4	More than $1,500,000	33
	Total	189

Table 3. Selected Cost Coefficients Used in LP Models

Source of Capital	Cost Coefficient (%)[a] 1966	1970	1974
Preferred stock[b]	4.63	4.70	5.15
Common stock[b]	3.92	4.10	4.84
Bank for Cooperatives[c]			
Term loans	5.79	8.29	9.09
Seasonal loans	5.58	8.08	9.03
Commercial bank[c]			
Term loans	5.71	8.46	10.81
Seasonal loans	6.06	8.45	10.54
Certificates of indebtedness[b]	5.09	5.56	6.86
Other sources[c]			
Term loans	5.85	8.48	9.24
Seasonal loans	5.62	8.24	9.18
Allocated savings or revolving fund capital[c]	6.86	8.93	9.21
Unallocated savings[d]	22–26	22–26	22–26

[a] Source: Cost coefficients for preferred stock, common stock, Bank for Cooperatives loans, commercial bank loans, other source loans, and certificates of indebtedness were obtained from financial statements of 189 Wisconsin farm supply cooperatives. Cost coefficients for allocated savings were obtained from Francl and Scheffel. The unallocated savings cost coefficients were obtained from Frattinger.
[b] Weighted average of cost coefficients used in LP models for representative firms from groups 1, 2, 3, and 4.
[c] Actual cost coefficients used in LP models for representative firms from all size groups.
[d] The 22% and 26% cost coefficients, respectively, are the federal income tax normal and surtax rates applicable to unallocated savings (reserves) of the cooperatives. These costs represent one-time charges assessed during the year in which the cooperatives accumulated the reserves.

operating statement figures for 1966 through 1972 for the 189 Wisconsin cooperatives were obtained from three regional cooperatives, private certified public accounting firms, and the local cooperatives themselves. The financial source and use figures for 1973 and 1974 were not yet available from these sources when this study was being conducted. However, possible effects on optimal solutions of the sharp rise in interest rates relative to preferred and common stock dividends that occurred during 1973 and 1974[5] seemed too important to ignore. Therefore, source and use of funds data for these two years were obtained by extrapolating the balance sheet and operating statement figures for 1966 through 1972 to 1973 and 1974. Cost coefficients used in the LP models (interest rates, preferred and common stock dividend rates, interest rates on certificates of indebtedness, etc.) for 1966 through 1974 were obtained from financial statements of the cooperatives and officials of lending agencies. Cost coefficients used for obtaining the 1966, 1970, and 1974 LP solutions appear in table 3.

In the LP models and also in computing capital costs for the existing financial structure, allocated savings (revolving fund) capital was priced at a level equal to the cost of short-term debt to farmer-members, a procedure similar to that used by Snider and Koller. The figures used in the study to represent the cost of short-term debt were weighted averages of short-term interest rates paid by Wisconsin farmers for short-term loans obtained from commercial banks and Production Credit Associations.[6] Assignment of this cost to allocated savings recognizes that member-

[5] For example, average interest rates charged by the St. Paul Bank for Cooperatives for seasonal and term loans averaged 5.88% in 1971 and 1972, only 1.14 percentage points higher than average preferred stock dividend rates paid by the Wisconsin farm supply cooperatives in this two-year period. In 1973 and 1974, the St. Paul Bank for Cooperative's interest rates for these same types of loans exceeded the preferred stock dividend rates paid by the cooperatives, which were lower than costs imputed to allocated debt relative to equity capital of the type just described would change substantially the optimal solutions and overall financing costs, it was thought to be important to include the 1973–74 period in the study to examine the effects of such changes.

[6] Allocated savings total a few hundred dollars or less for most Wisconsin farmer-members each year. If returned to the farmer, this money could substitute for short-term debt. Therefore, logic exists for pricing this capital at a cost equal to that for short-term debt. It can be argued that other types of equity capital such as preferred and common stock should be priced at the same rate as allocated savings. Actual stock dividend rates paid by the cooperatives, which were lower than costs imputed to allocated savings, were employed in the study for pricing stock, since these securities appeared to be a less risky investment for the farmer-member than allocated savings. For example, when a farmer-member retires or moves away from the trade area, some Wisconsin farm supply cooperatives will redeem his stock at par. This same farmer is less likely to be able to withdraw from the cooperative any allocated savings to which he may have a claim. The moderately greater liquidity and lower risk to the farmer on stock appeared to justify pricing this capital at the actual, lower dividend rates.

patrons may incur a relatively high opportunity cost when they supply capital to a cooperative. The assignment of this particular cost to revolving fund capital was a key aspect of the study that significantly influenced the results.

Special pricing and accounting procedures were used to accommodate the "artificial" cost represented by the interest charge placed on allocated savings. Interest charged on allocated savings is "artificial" in the sense that cooperatives typically do not actually pay this interest to farmer-members. Therefore, it can be argued that a cooperative's current liabilities should not be inflated by this interest charge. On the other hand, farmer-members do incur an opportunity cost on allocated savings retained by the cooperative. It is contended that a cooperative should consider this cost when deciding upon the mix of funds to use for financing growth and operations. The dilemma created by the dual character of this interest charge was resolved as follows: allocated savings were priced at the above mentioned short-term interest rate when computing the optimal financial structures with the LP models. Interest on allocated savings was included in the interest and dividends total in the balance sheets for the existing structure and those developed for the LP solutions.[7] However, in developing these balance sheets, the interest charges on allocated savings were subtracted from the other current liabilities figure to avoid creating an artificial net addition to current liabilities equal to this interest item.[8] This subtraction also performed the necessary function of keeping liabilities and equities equal to total assets on the balance sheets.

Results

Minimum Cost Capital Mixes

Use of allocated savings (revolving fund) capital was reduced substantially under the LP solutions. In the first LP solutions for the 1966–74 period, the models specified that long-term debt would be the primary substitute for revolving fund capital. However, the last solutions in the 1966–74 sequence called for financing needs of the cooperatives to be met to a greater extent by increased use of permanent equity capital (e.g., preferred and common stock) rather than revolving fund capital or long-term debt. Certificates of indebtedness comprised a substantial proportion of the long-term debt that remained in the last solutions in the sequence. Typically, financing costs were lower and cash patronage refunds substantially higher under the optimal solutions prescribed by the LP models than under the existing financial structure.[9]

Balance sheets for the existing financial structure and those compiled from the model II solutions for 1966, 1970, and 1974 for an average cooperative from the population of 189 firms appear in table 4. Results for model II (40% CPR, five-year revolving plan) are presented since they are representative of the optimal financial mixes prescribed by the various LP solutions and because it might be most feasible for cooperatives to follow prescriptions of model II, which call for relatively small departures from the present financing practices.

Financing costs (interest plus dividends) for the average cooperative under the model II solutions for 1966, 1970, and 1974, respectively, were $1,361 (7.1%), $2,522 (8%), and $3,306 (7.4%) lower than under the existing structure (table 4). Cash patronage refunds for 1966, 1970, and 1974, respectively, under model II were $3,899 (94.8%), $5,271 (90.8%), and $6,792 (83.8%) higher than under the existing structures.

Long-term debt totaled $55,822 (13.5% of total debt plus equity) under the existing structure in 1966. The model II solution for 1966 called for an approximate doubling of the amount of long-term debt to $112,141 (table 4). Allocated savings or revolving fund capital, which totaled $85,685 (20.8% of total debt plus equity) under the existing structure for 1966 was reduced to $12,020 (2.9% of total debt plus equity) under the model II solution for 1966 (table 4).

[7] It was necessary to include this interest charge in the existing balance sheets to make the existing balance sheet figures comparable to those developed from the LP solutions. This adjustment to existing balance sheets involved increasing the interest and dividends component of current liabilities by the amount required to price allocated savings at the short-term interest rate paid by farmer-members. Identical off-setting adjustments were made to the other current liabilities component of current liabilities to keep total current liabilities at actual levels.

[8] Other current liabilities include all current liabilities except interest and dividends, cash payments (cash patronage refunds) to farmer-members, and short-term loans from the Bank for Cooperatives, commercial banks, and other sources.

[9] The term "financial structure" as used here refers to the composition of debt and equity used by the cooperatives. Specifically, it refers to the amount of short- and long-term debt, certificate of indebtedness capital, preferred stock, common stock, allocated savings, and unallocated savings capital used by the cooperatives.

Table 4. Average Balance Sheets for 189 Wisconsin Local Farm Supply Cooperatives under Existing and Model II Financial Structures [a]

	Balance Sheet, 1966			Balance Sheet, 1970			Balance Sheet, 1974		
Balance Sheet Item	Existing Structure (1)	Model II (2)	Difference (2)-(1)	Existing Structure (3)	Model II (4)	Difference (4)-(3)	Existing Structure (5)	Model II (6)	Difference (6)-(5)
Current assets	$206,054	$206,054	0	$311,723	$311,723	0	$429,791	$429,791	0
Other assets	270,298	270,298	0	365,929	365,929	0	460,000	460,000	0
Total assets	$476, 352	$476,352	0	$677,652	$677,652	0	$889,791	$889,791	0
Short-Term Loans									
Bank for Cooperatives	$ 6,311	$ 16,378	$ 10,067	$ 16,756	$ 36,502	$ 19,746	$ 24,858	$52,487	$ 27,629
Commercial bank	2,017	—	(2,017)	4,535	—	(4,535)	5,488	—	(5,488)
Other sources	8,050	—	(8,050)	15,210	—	(15,210)	22,141	—	(22,141)
Interest plus dividends	19,092	17,731	(1,361)	31,338	28,816	(2,522)	44,947	41,641	(3,306)
Cash payments	4,115	8,014	3,899	5,804	11,075	5,271	8,104	14,896	6,792
Other current liabilities	41,061	41,061	0	71,544	71,544	0	99,172	99,472	300
Total current liabilities	$ 80,646	$ 83,184	$ 2,538	$145,187	$147,937	$2,750	$204,710	$208,496	$ 3,786
Long-term loans									
Bank for Cooperatives	$ 27,197	$ —	$(27,197)	$ 45,347	$ 35,392	$ (9,955)	$ 70,421	$ 84,360	$ 13,939
Commercial bank	2,284	99,868	97,584	10,521	59,921	49,400	14,751	19,974	5,223
Other sources	15,661	—	(15,661)	28,997	—	(28,997)	40,078	—	(40,078)
Certificates of indebtedness	10,680	12,273	1,593	14,103	19,824	5,721	17,789	32,983	15,194
Total long-term liabilities	$ 55,822	$112,141	$ 56,319	$ 98,968	$115,137	$ 16,169	$143,039	$137,317	$ (5,722)
Total liabilities	$136,468	$195,325	$ 58,857	$244,155	$263,074	$ 18,919	$347,749	$345,813	$ (1,936)
Preferred stock	$ 25,136	$ 25,810	$ 674	$ 25,135	$ 28,728	$ 3,593	$ 25,205	$ 31,982	$ 6,777
Common stock	202,533	216,667	14,134	253,308	284,008	30,700	308,008	372,767	64,759
Allocated savings	85,685	12,020	(73,665)	116,333	63,121	(53,212)	155,846	86,246	(69,600)
Unallocated savings	26,530	26,530	0	38,721	38,721	0	52,983	52,983	0
Total equity	$339,884	$281,027	$(58,857)	$433,497	$414,578	$(18,919)	$542,042	$543,978	$ 1,936
Total liabilities and equity	$476,352	$476,352	$ 0	$677,652	$677,652	$ 0	$889,791	$889,791	$ 0

[a] Source: Existing structure balance sheet figures represent averages of actual balance sheet figures for the 189 Wisconsin farm supply cooperatives that provided data for the study. Model II balance sheet figures are weighted averages of balance sheet figures developed from the LP optimal solutions generated by model II for representative cooperatives from groups 1, 2, 3, and 4.

The model II solution for 1970 prescribed that the average cooperative should use $115,137 of long-term debt (20.3% of total debt plus equity). This represents a 16.3% increase over the amount of long-term debt in the existing structure for 1970. Allocated savings or revolving fund capital under model II for 1970 totaled $63,121 (11.1% of total debt plus equity) as compared to $116,333 (20.4% of total debt plus equity) under the existing structure.

Model II called for use of $137,317 (18.7% of total debt plus equity) of long-term debt in 1974, which was $5,722 less than under the existing structure. The solution for 1974 prescribed use of $86,246 of revolving fund capital. This figure, which represented 11.8% of total debt plus equity, was 44.7% less than the amount of revolving fund capital used in the existing structure in 1974. Long-term debt and revolving fund capital were displaced partly by preferred and common stock capital in the optimum solution for 1974. These two permanent sources of equity capital totaled $404,749 under model II in 1974, or 21.5% more than under the existing structure.

The prescriptions in the 1970 and 1974 solutions calling for increased use of preferred and common stock were not surprising in view of the increase in interest rates relative to stock dividend rates in the 1970–74 period. As expected, the relatively high opportunity cost attached to allocated savings (revolving fund) capital caused the model to prescribe that cooperatives should use substantially less of this type of capital. Cooperatives, of course, could find it difficult to follow the model's prescriptions since farmer-members might not wish to purchase additional stock, especially if interest rates exceeded stock dividend rates by several percentage points, as in 1974. However, members would have some incentives to purchase additional stock despite the lower return on these securities. First, up to $200 of the stock dividends could be exempt from federal income taxes under the Internal Revenue Service dividend exemption provided to husbands and wives filing joint tax

returns. Second, members might purchase additional stock if this helped to maintain the cooperative as a competitive element in the farm supply business. Fenwick contends that the latter point is important (p. 69). In his study, he assumes that farmers will accept returns on investments in their farm supply cooperative that are about five percentage points lower than those obtained from investments in their farm businesses in order to maintain the cooperative as a viable market force. Thus, especially in areas where the second incentive assumes importance, cooperatives might find it feasible to follow prescriptions of the type produced by model II.

Cumulative Changes in Financing Costs and Cash Patronage Refunds

Accumulated financing cost reductions for 1966 through 1974 for the nine LP solutions appear in table 5. Under the different models, financing costs were from 6% to 13% lower than under the existing financial structure. Average financing cost savings per firm for the 1966–74 period ranged from $18,737 (model I) to $36,519 (model V). Average annual savings per firm for models II and VI, which prescribe 40% minimum cash patronage refunds, respectively, were $2,307 and $1,870.

Lengthening the revolving period had only modest effects on financing costs. Financing cost savings under models II, III, IV, and V, which have five-year revolving plans, were only 6.7% larger for 1966 through 1974 than under models VI, VII, VIII, and IX, which have ten-year revolving plans. Financing costs were a little less under the five-year revolving plan models because the relatively expensive revolving fund capital was used for shorter periods under these models.

Accumulated cash patronage refunds for the different LP solutions ranged from 4.9% lower (model I) to 375.4% higher (models V and IX) than those for the existing structure (table 5). For models II and VI, the average annual increase per firm in cash patronage refunds for 1966 through 1974 were $5,670 and $5,733, respectively. Cash patronage refunds were nearly identical under models II, III, IV, and V (five-year revolving plans) and under models VI, VII, VIII, and IX (ten-year revolving plans).

Impact of Optimal Plans on Liquidity and Solvency of Cooperatives

Robert Morris Associates current ratios and debt-equity ratios for 110 to 150 farm supply firms located throughout the United States and Canada were employed as standards for judging whether the prescriptions generated

Table 5. Changes Produced by Alternative Financing Plans for 189 Wisconsin Farm Supply Cooperatives, 1966–74[a]

	Accumulated Reduction in Financing Costs, 1966–74			Accumulated Change in Cash Patronage Refunds, 1966–74		
Model or Financing Plan	Total 189 Firms	Average Per Firm	% Reduction[b]	Total 189 Firms	Average Per Firm	% Change[c]
I (20% CPR)	$3,541,351	$18,737	6.89	$ (525,198)	$ (2,779)	(4.91)
II (40% CPR)	3,924,714	20,766	7.63	9,644,462	51,029	90.21
III (60% CPR)	4,961,536	26,252	9.65	19,805,922	104,793	185.26
IV (80% CPR)	5,937,039	31,413	11.54	29,965,686	158,549	280.29
V (100% CPR)	6,902,099	36,519	13.42	40,128,909	212,322	375.35
VI (40% CPR)	3,180,938	16,830	6.18	9,751,389	51,595	91.21
VII (60% CPR)	4,555,446	24,103	8.86	19,842,794	104,988	185.60
VIII (80% CPR)	5,755,277	30,451	11.19	29,966,967	158,555	280.30
IX (100% CPR)	6,874,709	36,374	13.37	40,128,876	212,322	375.35

[a] Source: Figures on accumulated capital cost reductions and cash patronage refund changes were obtained from data generated by the LP optimal solutions for representative cooperatives from groups 1, 2, 3, and 4 and from existing financing cost and cash patronage refund data for the cooperatives. Existing financing cost and existing cash patronage refund data required for computing the accumulated changes were obtained from the financial statements of the 189 Wisconsin farm supply cooperatives which provided data for the study.

[b] Percentages represent total financing cost reductions for 189 firms expressed as a percentage of the accumulated total financing costs ($51,432,852) for the 189 firms under the existing structure during 1966–74.

[c] Percentages represent total changes in cash patronage refunds for 189 firms expressed as a percentage of accumulated total cash patronage refund ($10,691,019) under existing structure during 1966–74.

by the models would reduce liquidity and solvency of the cooperatives excessively. A Robert Morris Associates median ratio (e.g., median current ratio) represents the ratio that lies in the middle of a group of ratios arrayed from "strongest" to "weakest." The upper quartile ratio lies halfway between the median and "strongest" ratio in the array. The lower quartile ratio lies halfway between the median and the "weakest" ratio in the array.

Officials of banks and lending agencies use these standard ratios for appraising whether a firm is financially strong and credit-worthy. Lenders generally conclude that a firm has average financial strength if its current and debt-equity ratios are about equal to the corresponding Robert Morris Associates median ratios. They consider a firm to be financially strong if its ratios are near the Robert Morris upper quartile ratios and financially weak if its ratios are near the Robert Morris lower quartile ratios.

High liquidity (strength) is indicated by large values of the current ratio. On the other hand, low solvency (weakness) is associated with high values for the debt-equity ratio.

Table 6. Robert Morris Associates Standard Financial Ratios and Average Financial Ratios for 189 Wisconsin Farm Supply Cooperatives and Group 4 Cooperatives under Alternative Financing Plans, 1966, 1970 and 1974[a]

	Current Ratio			Debt–Equity Ratio		
Model or Financing Plan and Standard Ratios	1966	1970	1974	1966	1970	1974
Average Figures for 189 Firms						
Existing structure	2.63	2.27	2:19	.40	.54	.62
Model I (20% CPR)	2.37	2.06	1.96	.66	.67	.62
Model II (40% CPR)	2.30	2.04	1.95	.68	.60	.59
Model III (60% CPR)	2.23	1.97	1.87	.69	.67	.67
Model IV (80% CPR)	2.17	1.89	1.80	.69	.76	.76
Model V (100% CPR)	2.11	1.83	1.73	.71	.85	.86
Model VI (40% CPR)	2.30	2.07	1.99	.68	.57	.45
Model VII (60% CPR)	2.23	1.98	1.91	.69	.64	.55
Model VIII (80% CPR)	2.17	1.90	1.82	.69	.73	.67
Model IX (100% CPR)	2.11	1.83	1.73	.71	.82	.84
Robert Morris Standards[b]						
Upper Quartile Ratio[d]	—	3.13	2.50	—	.42	.68
Median Ratio	1.94	1.97	1.63	.85	.90	1.29
Lower Quartile Ratio[d]	—	1.44	1.19	—	1.66	2.54
Average Figures for Group 4 Firms						
Existing structure	2.60	2.03	2.05	.40	.63	.70
Model I (20% CPR)	2.31	1.78	1.72	.76	.88	.82
Model II (40% CPR)	2.19	1.76	1.69	.79	.78	.85
Model III (60% CPR)	2.10	1.67	1.60	.78	.91	.99
Model IV (80% CPR)	2.02	1.59	1.52	.75	1.06	1.15
Model V (100% CPR)	1.94	1.52	1.45	.73	1.24	1.34
Model VI (40% CPR)	2.19	1.77	1.78	.79	.72	.55
Model VII (60% CPR)	2.10	1.69	1.66	.78	.83	.73
Model VIII (80% CPR)	2.02	1.61	1.56	.75	.95	.94
Model IX (100% CPR)	1.94	1.54	1.47	.73	1.08	1.21
Robert Morris Standards[c]						
Upper Quartile Ratio[d]	—	2.50	2.10	—	.40	.90
Median Ratio	2.30	2.00	1.70	.64	.90	1.50
Lower Quartile Ratio[d]	—	1.50	1.20	—	1.10	3.10

[a] Source: Current ratio and debt-equity ratio averages for 189 firms were computed from actual average balance sheet figures for the firms and from weighted averages of balance sheet figures generated by the LP optimal solutions for group 1, 2, 3, and 4 cooperatives. Average current ratios and debt-equity ratios for group 4 firms were computed from balance sheet information developed from the LP optimal solutions for the representative cooperative from group 4. Robert Morris standard ratios were obtained from Robert Morris, *Annual Statement Studies*.

[b] Standard ratios employed for appraising liquidity and solvency of the average cooperative from the group of 189 firms were based on average ratios reported by all farm supply firms from which Robert Morris Associates collects data.

[c] Standard ratios employed for appraising liquidity and solvency of group 4 cooperatives are based on average Robert Morris Associates figures for farm supply firms similar in size to the group 4 cooperatives.

[d] No Robert Morris Associates standard upper and lower quartile ratio figures were available for 1966.

Therefore, upper quartile value figures for the Robert Morris current ratio standards are larger than the median values, and upper quartile figures for the debt-equity ratio standard ratios are smaller than the median values (table 6).

The current ratios (used to measure liquidity) for the average Wisconsin farm supply cooperative fell below the Robert Morris Associates median ratios only under models V and IX, which specified that 100% of patronage refunds be paid in cash. Current ratios of the larger group 4 firms, whose liquidity was lower than average under the existing structure, generally fell below Robert Morris Associates median liquidity ratios for like-sized firms under plans II, III, IV, V, VI, VII, VIII, and IX, which called for payment of 40% or more of patronage refunds in cash. However, even for these plans, the current ratios of the group 4 firms still remained above the lower quartile Robert Morris Associates current ratios (table 6).

The debt-equity ratios (used to measure solvency) for the average Wisconsin cooperative remained below the Robert Morris Associates median values under models I thorugh IX. However, for the large group 4 firms, the debt-equity ratios for plans that called for payment of 60% or more of the patronage refunds in cash generally were higher than the Robert Morris Associates median figures.

The implication of the above is that it would be feasible for cooperatives to adopt alternatives to the commonly used 20% cash patronage refund plans. If the average cooperative used capital acquisition practices similar to those prescribed by the models, it generally could pay 40% or 60% cash patronage refunds without jeopardizing its solvency or liquidity.

Effects of Mandatory Equity Retirement Plans on Solvency of Cooperatives

Under the hypothetical mandatory equity retirement plan examined in the study, representative farm supply cooperatives would retire each year the equity capital of members who die, retire, or leave the area served by the cooperative and would replace the equity capital paid out to former members under the plan with long-term debt. Simulation of the impact of the plan involved modifying the balance sheets of the representative cooperatives from groups 1, 2, 3, and 4 to reflect effects on solvency of replacing the equity capital with debt. (A description of the size and number of cooperatives in each group is given in table 2.) In order to perform the simulation it was necessary to get estimates of the average amount of equity capital held by members who die, retire, or leave the cooperatives each year. The needed information (table 7) was obtained from telephone interviews of a stratified random sample of officials employed by 83 of the 189 Wisconsin farm supply cooperatives.

The statistic $Diff_2$ was used to measure how much solvency of the cooperatives would have declined if management had been required to replace the equity capital represented by the percentages in table 7 each year during 1966 through 1974 with long-term debt. $Diff_2$ equals the Robert Morris Associates median debt-equity ratio, $(D/E)_{ts}$, minus the debt/equity ratio of the representative cooperatives under the mandatory equity retirement plan, $(D/E)_{mer}$. Note that $Diff_2$, which goes negative when a cooperative's debt-equity ratio rises above the Robert Morris standards, became negative for all four representative cooperatives within two years after the mandatory equity retirement plan became operational (figure 1).

Solvency ratios declined most sharply under the mandatory equity retirement plan for the group 1 and 3 cooperatives, which had larger than average amounts of equity capital in their existing financial structures. The debt-equity ratios for the group 1 cooperative, for example, rose above the Robert Morris Associates lower quartile debt-equity ratios in 1973, indicating that solvency of the small firms in this group deteriorated substantially under the hypothetical equity retirement plan.

Statistic $Diff_1$ (figure 1) shows that the

Table 7. Average Percentage of Cooperative's Equity Capital Held by Members Who Die, Retire or Leave Trade Area Annually[a]

Cooperative Group	Percentage of Equity Held by Members Leaving Cooperative Each Year
1	9.47
2	8.81
3	8.85
4	8.48

[a] Source: Figures were obtained from interviews of officials employed by 83 of the 189 Wisconsin farm supply cooperatives.

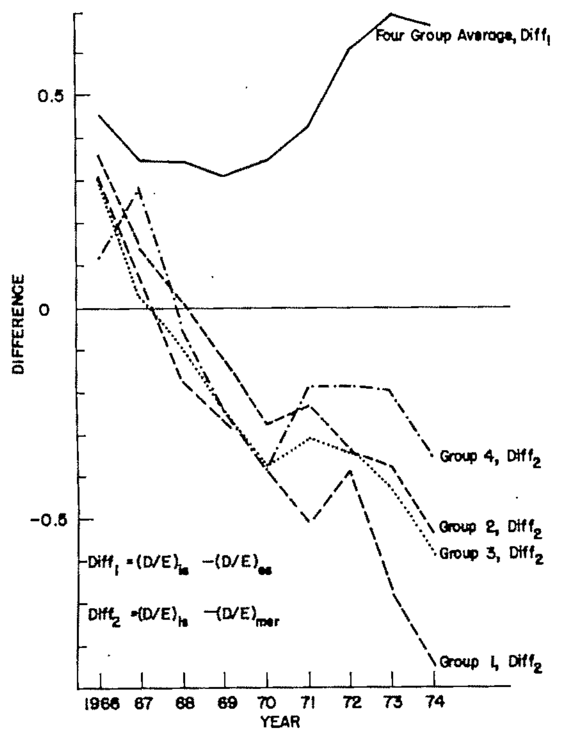

Figure 1. Comparison of Robert Morris Associates median debt-equity ratios to debt-equity ratios for existing financial structure and debt-equity ratios under mandatory equity retirement plan

mandatory equity retirement plan was not a factor that simply exacerbated an already deteriorating solvency condition among the firms. $Diff_1$ is the Robert Morris Associates median debt-equity ratio, $(D/E)_{ts}$, minus the actual average debt-equity ratio of the representative cooperatives, $(D/E)_{es}$. The positive and increasing values for $Diff_1$ (figure 1) show that actual debt-equity ratios for the average Wisconsin farm supply cooperative declined during 1966 through 1974 relative to the Robert Morris Standards. Thus, the mandatory equity retirement plan would have caused the decline in solvency in firms, which otherwise would have maintained strong solvency positions.

This study admittedly examined only one basic type of mandatory equity retirement scheme. However, many other proposed equity retirement plans do have similar characteristics and therefore might produce similar effects. For example, one other equity retirement plan would require cooperatives to retire each year the equity capital of members who die, retire, or move away from the cooperatives trade area and also pay off some proportion of the equity capital held by those members who left the organization in earlier years. Since retiring the equity capital of those who leave each year could substantially reduce solvency of farm supply cooperatives, any obligation to retire additional equity capital could put an especially heavy debt burden on the firms. The implication of this part of the study seems clear. Lawmakers who are considering mandatory equity retirement plans for agricultural cooperatives should examine whether enacting these bills into laws would place an excessive debt load on the cooperatives.

Summary and Implications

An optimal or least-cost financial structure for Wisconsin farm supply cooperatives would include more permanent equity capital (e.g., preferred and common stock), more certificates of indebtedness capital, and substantially less revolving fund capital. In the study the least cost financial mix included less revolving capital primarily because this capital was priced at a rate equal to the cost of short-term debt to recognize the opportunity cost incurred by farmers who supply capital to a cooperative. Financing costs under the least cost solutions for the 40% and 60% cash patronage refund plans were about \$2,100 (7%) and \$2,800 (9%) per year lower, respectively, than actual financing costs of the average Wisconsin farm supply cooperative during 1966 through 1974. The average cooperative might find savings of this size attractive since the firm could achieve these savings while increasing cash refunds to members by about 90% under the 40% cash patronage refunds plan and 185% under the 60% cash patronage refund plans.

The dynamics of achieving the optimal mixes would have the cooperatives use more long-term debt as an interim measure, while gradually increasing sales of preferred and common stock. Frequently, the market for a cooperative's stock is limited since capital appreciation and dividends on the stock are modest and restrictions exist on transfer of the stock. Therefore, farmer-members might need to be the primary customers for additional stock issued. Members would have these incentives to purchase additional stock. First, dividends on the stock might be attractive compared to returns on funds tied up in a

revolving fund that fails to revolve or revolves sporadically. Second, up to $200 of stock dividends each year would be exempt from federal income taxes. Finally, members might purchase stock that pays modest dividends if this helped to maintain the cooperative as a viable competitor in farm supply markets. Cooperatives, of course, also might need to pay moderately higher dividends in order to sell more stock. The amount that cooperatives would have to raise dividends to produce desired stock sales would vary from firm to firm and might be influenced by how much the farmer-member valued keeping the cooperative as a viable competitor and by the nonmonetary benefits secured from holding membership in the organization.

Liquidity and solvency of the average cooperative were satisfactorily maintained under the 40% and 60% cash patronage refund plans examined in the study. Therefore, if the cooperatives could succeed in selling the required amounts of stock, they apparently would find it feasible to develop financing plans that would lower sacrifices of members, reduce capital costs, and substantially increase cash patronage refunds.

Former members or inactive members would benefit if the farm supply cooperatives developed systematic plans for retiring the equity capital of members who die, retire, or move from the cooperative's service area. But if the cooperatives were required to implement equity retirement plans of the type considered in this study, this could substantially reduce the solvency of many of these firms.

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Acreage Response and Demand for Processing Tomatoes in California

Wen S. Chern

A theory of contracting is developed to show how acreage and price might be determined in the raw tomato market. The paper estimates the structural parameters of the acreage response and demand for processing tomatoes facing California growers. Several hypotheses of leadership pricing are tested. Results show that the California processing industry can be characterized as a competitive industry, since the leadership pricing as observed is consistent with the competitive pricing. Acreage response is shown to be price elastic. The adoption of the tomato harvester is found to have a significant impact on acreage response.

Key words: acreage, contracting, econometric analysis, elasticity, leadership pricing.

Over the last two decades, California has been the most important state in producing processing tomatoes in the United States. In 1974, California produced 4.8 million tons of processing tomatoes, which accounted for 83% of the U.S. production. Most processing tomatoes have been produced under contractual arrangement in California. The market structure has been such that most processors commonly follow price leadership in negotiating contract price with growers (Collins et al.). The study develops a theory of contracting that shows how acreage and price might be determined in the raw tomato market and estimates the structural parameters of the acreage response and demand for processing tomatoes facing California growers.[1]

The major objective of this paper is to relate empirical results to several hypotheses of leadership pricing and to test whether the results are consistent with a particular theory. Also, the empirical results provide a basis for further analysis of the processing tomato industry.

Economic Analysis of Contracting

The analysis of contracting deals with the determination of acreage and price within the structure of the raw tomato market. Theoretically, acreage and price are determined by supply and demand, which can be derived from growers' and processors' profit maximization conditions.

A Static Economic Model

Define the following variables: A = acreage to be contracted, Y = yield per acre, Y^* = expected yield, $Q = AY$ = quantity produced from contracted acreage, $Q^* = AY^*$ = expected quantity to be produced, P_c = contract price per ton of raw tomatoes, and P_j^* = expected price of final product j.

Suppose that the growers' objective is to maximize profit subject to technological and contractual constraints. Begin with the production function $Q = Q(A, X_1, X_2, X_3)$, where X_1 is labor, X_2 is fertilizer, and X_3 is capital. It is assumed that all marginal products are nonnegative and Q is a strictly concave function (at least in the economically relevant region). Furthermore, the cost

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[1] Theoretically, one cannot separate the demand for California processing tomatoes from the demand for the same product in other states. Fortunately, it was found that production in other states has been relatively stable without any significant trend over the period under consideration. The increasing trend of yield in other states has been offset by the declining trend in acreage. The fact that relatively constant production has prevailed in other states facilitates the treatment of the demand for raw tomatoes facing California growers.

function is specified as $C = k + w_0A + w_1X_1 + w_2X_2 + w_3X_3$, where k, w_0, w_1, w_2, and w_3 are, respectively, fixed-cost and input prices for A, X_1, X_2, and X_3.

The profit function can then be expressed as $\Pi_g = P_cQ - C$. The problem is to maximize Π_g subject to $Q \leq Q^*$, $A \geq 0$, and $X_i \geq 0$ for $i = 1, 2,$ and 3. This is a nonlinear optimization problem. Noting $Q^* = AY^*$, one can derive the solutions for A and the X_i's from the Kuhn-Tucker conditions for a maximum. The resulting equations are generally termed the input demand functions. Our major interest is in the equation for acreage, namely,

$$(1) \quad A^s = A^s(P_c, w_0, w_1, w_2, w_3, Y^*).$$

Equation (1) can be viewed as the derived demand function for acreage with respect to w_0. It can also be treated as a derived supply function of acreage with respect to P_c. In general, it can be termed the acreage response equation.

Consider next the processors' demand for acreage in tomato contracting. Since there are much fewer processors than growers in the industry, it is plausible to assume that the processors procure raw tomato supply in a so-called oligopsonistic market. The equilibrium conditions for an oligopsonistic entrepreneur are, in general, difficult to derive because the reactions of his rivals can hardly be predicted whenever he adopts a pricing policy. Fortunately, the situation in the California tomato industry might be more straightforward. The industry was typified by price leadership (Collins, Mueller, and Birch). As a result, most processors view price as given in negotiating a contract with growers. We focus here on the study of the behavior of price-taking processors.

The processor is faced with a two-stage decision process. First, he has to determine the total quantity of raw tomatoes that he needs. Then he has to estimate the acreage needed according to his expectation of yield.

Suppose all processed products can be measured in proportion to the raw tomatoes utilized; that is, $V_j = r_jQ_j$, where V_j is the quantity of the jth processed product, r_j is the product transformation ratio for the jth product, and Q_j is the quantity of raw tomatoes used for product j. Assume further that the processing cost function for the jth product is given by $S_j = S_j(V_j) = S_j(r_jQ_j)$. This cost function is net of the cost of purchasing raw tomatoes. Disregarding inventory, the processors' expected profit function at the time of contracting is formulated as

$$\Pi_p = \sum_{j=1}^{k} P^*_j r_j Q_j - \sum_{j=1}^{k} S_j(r_jQ_j) - P_c \sum_{j=1}^{k} Q_j.$$

From the first-order condition of profit maximization, one can derive the demand function for raw tomatoes as $Q_j = Q_j(P_c, P^*_j; r_j)$ for $j = 1, \ldots, k$. The total demand for raw tomatoes is simply the sum of the Q_j's. This can be expressed in a general form as

$$(2) \quad Q^d = \sum_{j=1}^{k} Q_j = Q^d(P_c, P^*_1, \ldots, P^*_k; r_1, \ldots, r_k),$$

where $r_1, \ldots, r_k$ are fixed parameters in the equation.

In order to make contracts with growers, the processor has to decide on specific terms in regard to acreage. Since yield is not known at the time of contracting, acreage has to be derived according to the yield expectation:

$$(3) \quad A^d = Q^d/Y^*.$$

The acreage response function was derived from a single-product production function. While the treatment of a multiproduct production function would substantially complicate the theoretical model, it can be implemented in our empirical analyses by introducing the prices of competing crops in the acreage response function.

The static model as developed so far has not considered the effect of technological change. The adoption of the tomato harvester in the late 1960s has drastically altered harvesting operations. It is, therefore, important to know the extent to which the mechanization in harvesting has changed the structural parameters in both acreage response and raw tomato demand functions.

Price Determination

Stigler has classified two general cases of price leadership. One is the dominant firm leadership, and the other is the barometric firm hypothesis. In the former case, a dominant firm sets the price, while the minor firms buy what they wish at this price. The price leadership in the other case refers to the existence of a firm that conventionally first announces price changes that are usually followed by the other firms in the industry, even though the barometric firm may not occupy a dominant position.

As noted by Collins et al. and by our own observation through informal interviews with growers, the barometric type of price leadership has been commonly exercised in the Californian tomato industry. It is known that the price set by the leader firm may be competitive, monoponistic, or somewhere in between. If the leader firm fully complies with the market situation and sets a competitive price, the market can be viewed as a more or less competitive market in which A, Q, and P_c are simultaneously determined. If the contract price, P_c, is solely determined by leadership firms in a noncompetitive situation, it is exogenous in the system.

Treatment of Unobservable Variables

Expected yield and expected product prices in equations (1) and (2) are not observable at the time when growers and processors are negotiating for a contract. It is, therefore, necessary to know how growers and processors form their expectations.

It seems reasonable to assume that the grower formulates his yield expectation according to past yields. Nerlove has postulated an adaptive expectation model that leads to a geometrically declining lag formulation. Behrman later extended Nerlove's model by introducing an additional factor to account for abnormalities in rainfall. All these elaborated expectation models are difficult to implement in the present study because the number of independent variables is fairly large in the acreage supply equation and consequently the problem of degrees of freedom will be severe. For this reason, the following formulation is proposed:

$$E(Y_t|Y_{t-1}, \ldots) = \sum_{i=1}^{n} \lambda_i \, Y_{t-1},\ n = 2, 3, \ldots,$$

where λ_i's are some weights to be specified and $\Sigma\lambda_i = 1$.

The grower is subject to risk while making yield predictions. The mean-variance criterion has been widely adopted in measuring risk (Tobin, Behrman). This criterion appears to be the most relevant approach for application in this study.

Prices of processed tomato products are not observable at the time of contracting. However, information on current prices and inventory conditions could be used for predicting future prices. Also, the level of consumer incomes for the coming season could be easily projected. Therefore, it seems plausible to assume that $P^*_j = f(R_1, \ldots, R_k, I_j, M)$, in which R_j is the current price of jth product, I_j is the inventory at the time of contracting, and M is the projected consumer income. The important aspect of risk is not investigated for product prices because product prices are relatively more certain than yield, especially when price of raw tomatoes is under contract.

Econometric Variables

The preceding conceptual analysis has derived the fundamental functional relationships describing the California tomato economy. Before preceding with estimating these relationships, it is important to discuss the specific variables used in the analysis.

The first structural equation is acreage response, in which contract acreage, A_c, is expressed as a function of grower price, P_c, wage rates, Z_2, adoption rate of the tomato harvester, Z_4, price of ammonium nitrate, Z_5, average yield of the preceding three years, Y_a, standard deviation of yields in the preceding three years, D, and lagged prices of competing crops including sugar beets, $S_{p,t-1}$, grain sorghum, $G_{p,t-1}$, and alfalfa hay, $H_{p,t-1}$.

Grower prices are average prices of tomatoes purchased from contracted acreage. Wage rates for the preharvesting period are used because complete data for the harvesting period are not available. Since June is the peak month for labor demand in preharvesting operation, the wage rate in June is used for analysis. The average of wage rates in San Joaquin and Yolo counties (two major counties in producing tomatoes) is taken as the average rate for the state. The reported price of ammonium nitrate in California is used as the input cost of fertilizer.

Several formulations of yield expectation were tried in the preliminary analyses. The average yield of the preceding three years was found to be superior to using a one-year lag or the average of the preceding two years. Correspondingly, the standard deviation of the yields in the preceding three years is taken as the indicator measuring risk in yield expectation.

Due to a large number of alternative crops found in the major tomato-producing counties, it is rather difficult to single out the one or two most important competing crops. Sugar

beets, grain sorghum, and alfalfa hay were considered to be more important competitive crops and therefore were chosen for our empirical analysis.

Virtually all tomatoes were harvested by hand before 1963. In contrast, more than 95% of processing tomatoes have been harvested by mechanical harvesters since 1968. The period 1964–67 was a transition period with mechanical harvesting gradually replacing hand harvesting. The degree of mechanization is measured by the adoption rate of the tomato harvester.

The second structural equation is the demand for processing tomatoes, Q_c, expressed as a function of grower price, P_c, total April 1 inventory of five major tomato products, Z_7, the weighted FOB price of five major tomato products, R, and per capita consumer incomes, Z_{10}.

The total quantity demanded, Q_c, cannot actually be observed at the time of contracting. An approximation is therefore required. To a limited extent, open market purchases can be used by the processor to fill the gap between the desired quantity and the actual quantity produced from the acreage to be contracted. Thus, the sum of the quantity from the contracted acreage and the quantity purchased from the open market is taken as the quantity indicator of the processors' demand at the time of contracting.

Due to the limited degrees of freedom from the relatively small sample size, it is not feasible to include the prices of all processed tomato products in the demand equation. Contracts are generally made in the period January through April before each season starts. Assuming that processors utilize the most recent information about the prices of tomato products for their decisionmaking, the weighted average FOB price, R, is computed as

$$R = \sum_{j=1}^{5} \beta_j R_j,$$

in which R_j is the average FOB price of product j during January through March, β_j is the weight specified as the percentage of total shipments of product j (in a standardized 24/303 case basis) during this period, and the five products are canned tomatoes, tomato juice, paste, puree, and catsup.[2]

The last two variables affecting the processors' demand for raw tomatoes are inventory and consumer incomes. To conserve degrees of freedom, the sum of the April 1 inventories of the five major products is used. Furthermore, the actual seasonally adjusted annual averages (in fiscal years) of disposable personal incomes are used as the projected figures at the time of contracting.

The final behavioral equation is the quantity-acreage relation expressing A_c as a function of Q_c and Y_a.[3]

Empirical Results

In California, tomato production has been concentrated in ten major counties, which have accounted for more than 85% of the state's production in recent years.[4] In this paper, only the empirical results obtained from the analysis based on these ten counties are presented, even though the results obtained for the state as a whole show no significant differences (as reported in Chern).[5]

Annual econometric models for the post-World War II period 1951–72 are constructed. Both linear arithmetic and linear logarithmic forms were tried as alternative functional specifications. It was found that in most cases both formulations performed equally well. However, only the results of logarithmic form are presented here. The adoption rate of the tomato harvester, Z_4, would not take a logarithmic transformation because its values are zero for many years.

One important aspect of our empirical analysis is the investigation of the behavior of the grower price, P_c, in the system. As pointed out previously, under the noncompetitive leader-firm pricing hypothesis, the grower price is determined solely by a leader firm and is exogenous in the system. Consequently, the structural equations can be appropriately estimated by ordinary least squares (OLS) under the usual condition (i.e., the variance-covariance matrix $\Sigma = \sigma^2 I$) about the disturbance terms. On the other hand, if the raw tomato market follows more or less a competi-

[2] Tomato sauce is not included because complete data on its shipments are not available.

[3] A_c is measured in thousand acres, Q_c in thousand tons, P_c in dollars per ton, Z_2 in dollars per hour, Z_4 in percent, Z_8 in dollars per ton, Y_a in tons per acre, D in tons per acre, $H_{p,t-1}$ and $S_{p,t-1}$ in dollars per ton, $G_{p,t-1}$ in dollars per bushel, R in dollars, Z_7 in 24/303 million cases, and Z_{10} in billion dollars.

[4] The ten counties are San Joaquin, Yolo, Fresno, Solano, Sutter, Sacramento, Stanislus, Merced, Santa Clara, and San Benito.

[5] Thus, A_c and Q_c are, respectively, contract acreage and purchased quantity of tomatoes in the selected ten counties. However, for all other variables, state data are used. Complete data used in this study are available in Chern.

Table 1. Estimated Acreage Response and Demand for Processing Tomatoes, 1951–72

Equation set	Normalized variable	Estimation method	$\ln P_c$	$\ln Z_2$	Z_4	$\ln Z_8$	$\ln Y_a$	$\ln D$	$Z_4 \ln P_c$	$\ln R$	$\ln Z_{10}$	$\ln Q_c$	Constant	R^2	d
1.1	$\ln A_c$	3SLS	1.704	−2.636	.0041	−4.023	2.291	−.028					23.02	.80	
			(.31)	(.63)	(.002)	(.78)	(.52)	(.05)					(4.39)		
		OLS	.910	−1.390	.0021	−3.34	1.298	−.057					19.55	.88	3.08
			(.18)	(.49)	(.002)	(.63)	(.41)	(.04)					(3.65)		
2.1	$\ln Q_c$	3SLS	−.701							1.363	.624		4.13	.85	
			(.46)							(.41)	(.10)		(.95)		
		OLS	−.249							1.012	.603		3.32	.87	1.76
			(.26)							(.30)	(.09)		(.65)		
3.1	$\ln A_c$	3SLS					−.441					.861	−.639	.91	
							(.19)					(.08)	(.42)		
		OLS					−.354					.813	−.514	.91	1.21
							(.18)					(.08)	(.41)		
1.2	$\ln A_c$	3SLS	1.658	−2.568		−4.062	2.248	−.029	.00112				23.15	.80	
			(.31)	(.61)		(.78)	(.51)	(.05)	(.0006)				(4.41)		
		OLS	.883	−1.358		−3.353	1.275	−.057	.0006				19.62	.88	3.07
			(.18)	(.46)		(.63)	(.40)	(.04)	(.0005)				(3.65)		
2.2[a]	$\ln Q_c$	3SLS	−.701							1.364	.624		4.13	.84	
			(.46)							(.41)	(.10)		(.95)		
3.2[b]	$\ln A_c$	3SLS					−.441					.861	−.639	.91	
							(.19)					(.08)	(.42)		
1.3	$\ln A_c$	3SLS	1.758	−2.123		−4.359	2.209						22.29	.77	
			(.33)	(.43)		(.80)	(.46)						(4.26)		
		OLS	.920	−1.203		−3.459	1.413						18.92	.85	2.78
			(.19)	(.32)		(.66)	(.36)						(3.63)		
2.3[a]	$\ln Q_c$	3SLS	−1.195							1.756	.646		5.01	.78	
			(.58)							(.49)	(.12)		(1.16)		
3.3[b]	$\ln A_c$	3SLS					−.456					.872	−.676	.91	
							(.19)					(.09)	(.42)		

Note: The figures in parentheses are estimated standard errors; R is the correlation between the observed and estimated values of the normalized variable; and d is the Durbin-Watson statistic.

[a] OLS estimate is the same as in 2.1.

[b] OLS estimate is the same as in 3.1.

tive market system, the grower price is then determined at the equilibrium conditions where demand equals supply. A simultaneous equation system is appropriate and, hence, the structural equations have to be estimated by simultaneous system approaches. Under the usual conditions, both two-stage least squares (2SLS) and three-stage least squares (3SLS) give consistent estimates of the structural coefficients. Since 3SLS is theoretically more efficient than 2SLS, only 3SLS estimates are presented.[6]

Estimated Structural Equations

Table 1 contains the final sets of estimated equations.[7] With a few exceptions, all estimated coefficients appearing in the equations presented in table 1 have a t-ratio greater than two.[8] The variables Z_4, D, and $Z_4 \ln P_c$ are sensitive to estimation methods. Specifically, Z_4 is significant only when 3SLS is applied. Since Z_4 is an important variable for making inferences about the impacts of harvesting mechanization and D is an interesting variable for measuring risk, the presentation of some variants with and without these two variables appears to be warranted. The interaction variable, $Z_4 \ln P_c$, is included to investigate whether the introduction of tomato harvesters

[6] The differences between 2SLS and 3SLS estimates are notable in some cases, and in general the coefficients estimated by 3SLS are slightly larger in absolute value and the estimated standard errors are smaller than those obtained by 2SLS.

[7] Detailed results obtained from a systematic elimination of insignificant variables from the entire set of variables originally proposed are available in Chern. As turned out, the model failed to identify crops competing with processing tomatoes. This is perhaps because there are too many alternative crops, and hence no single crop can show a significant impact at the aggregate level. Further investigation at the county level is currently under way and will be reported elsewhere.

[8] The reliability of an estimated coefficient can be established by carrying out the student t-test. It is well known that the t-test and the Durbin-Watson statistic are strictly valid only when OLS is applied. The standard errors for the 3SLS estimates refer to asymptotic distributions and their validity in small samples is not generally known.

has affected the price elasticity. Unfortunately, the extremely high correlation between Z_4 and $Z_4 \ln P_c$ precludes a possible formulation to include these two variables in the same equation. For the purpose of comparison, they are separated out in two equations as shown in equations (1.1) and (1.2).

Consider the highlights of our findings. The first equation set consists of three structural equations. Equation (1.1) shows that grower price, $\ln P_c$, wage rates, $\ln Z_2$, fertilizer price, $\ln Z_5$, and lagged average yield, $\ln Y_a$, are significant factors influencing the grower's acreage response as estimated under both methods. The adoption of mechanical harvesters, Z_4, shows a significant impact only when 3SLS was applied. In equation (2.1), all three variables, i.e., grower price, $\ln P_c$, weighted FOB price of tomato products, $\ln R$, and consumer incomes, $\ln Z_{10}$, are significant in determining the demand for processing tomatoes. Finally, equation (3.1) shows that the processor demand for acreage is plausibly explained by its expected yield, $\ln Y_a$, and quantity demanded, $\ln Q_c$.

Primary interest lies in the equations of acreage response and demand for processing tomatoes. The most important variable under investigation is, of course, the grower price, P_c. The most crucial variable for comparing different estimation methods appears to be P_c in the demand function for processing tomatoes. As shown in equation (2.1), the coefficient of $\ln P_c$ estimated by OLS is -0.25, which is substantially smaller in absolute value than the 3SLS estimate, -0.70.

When OLS is applied, the multiple coefficient of determination R^2 measures goodness of fit. Under 3SLS, R is the correlation coefficient between the actual and estimated values of the normalized variable. In general, R^2's are reasonably high, indicating good performance of the model. The Durbin-Watson test for OLS estimation does not suggest presence of positive first-order serial correlation except perhaps for equation (3.1), in which this statistic falls into the inconclusive region.

The second set of equations differs from the first set only in that Z_4 is replaced by $Z_4 \ln P_c$. The estimation of the demand for processing tomatoes and the acreage-quantity relation remains unchanged when OLS was used. In the acreage response equation, no significant changes were found. The estimated coefficient of $Z_4 \ln P_c$ has a reasonably high t-ratio only when 3SLS is used.

Variables Z_4, $\ln D$, and $Z_4 \ln P_c$ do not appear in the last set of equations. The elimination of these variables does not disturb the OLS estimates of equations (2.3) and (3.3), which remain unchanged from equations (2.1) and (3.1). The effects on the OLS estimates of equation (1.3) are also minimal. A fairly dramatic "improvement" is found for the estimated coefficient of the grower price in the demand equation when 3SLS is applied. The 3SLS estimate of the grower price coefficient (elasticity) become greater than one in absolute value, and the t-ratio is much improved.

Based on the estimated standard errors of estimated coefficients and on R^2, the model has performed fairly successfully in estimating the structural equations. The selection of particular estimation methods was made largely on a priori grounds according to the assumed market system. Therefore, the performance of various estimation procedures might be used as an informal test of hypotheses that we have made regarding market structure. Since the OLS estimate of the coefficient of P_c in the demand equation is not statistically significant, the simultaneous equation model appears to be more appropriate than the single-equation specification. In other words, the California processing industry can be characterized as a more or less competitive industry in the sense that the leadership pricing as observed is consistent with the competitive pricing.

Comparison of Elasticities

One of our objectives is to obtain estimates of the important elasticities for acreage response and demand for processing tomatoes. The knowledge of these elasticities would be quite useful for further policy analyses (e.g., Schmitz and Seckler). Since the results presented earlier appear to be sensitive to estimation methods, it would be of some importance to point out the extent to which the resulting elasticities differ.

Price elasticities estimated by OLS are substantially smaller than those estimated by 3SLS.[9] Specifically, results indicate that acreage response has a unitary elasticity using OLS and is elastic (1.7) using 3SLS.[10] The

[9] This holds also when arithmetic form is used. It is also found that the price elasticities obtained from the arithmetic specification are consistently smaller than those obtained from their comparable equations in logarithmic form.

[10] In dealing with the supply response of planted acreage of processing tomatoes, Babb, Belden, and Saathoff estimated the short-run and long-run price elasticities, respectively, as 2.18 and

exclusion of Z_4 and D from the system results in greater estimates of demand elasticities with respect to grower price as well as weighted product price. Furthermore, demand elasticities with respect to grower price estimated by OLS are substantially smaller (in absolute value) than those estimated by 3SLS. The results in equation (2.3) show that the demand for processing tomatoes has a unitary elasticity with respect to grower price as estimated by 3SLS and is inelastic using OLS estimation. Moreover, demand is elastic with respect to tomato product prices, R, and inelastic with respect to consumer incomes, Z_{10}, in all cases.

In order to derive the relevant elasticities associated with the processors' demand for acreage, it is necessary to consolidate the demand for raw tomatoes and the acreage-quantity relation. The acreage demand elasticities can be obtained simply by multiplying the relevant coefficients in the demand equation for processing tomatoes by the coefficient of $\ln Q_c$ in the acreage-quantity equation. Using estimated equations (2.3) and (3.3), the resulting elasticities for acreage demand are presented in table 2. The elasticities of the demand for acreage are uniformly smaller than the elasticities of the demand for processing tomatoes. However, the differences between these two sets of elasticities are quite small.

Impacts of the Adoption of the Tomato Harvester

Mechanization is generally regarded as a labor-saving technological innovation. The adoption of the mechanical tomato harvester has changed the cost structure considerably for harvesting tomatoes (King, Jesse, and French). Since the underlying production function was essentially altered by this technological change, it is important to know whether the introduction of the tomato harvester has made any drastic structural changes in growers' acreage response. Variable Z_4 was included to reflect the impacts of harvesting mechanization, as shown in equation (1.1) in table 1.

As noted earlier, the coefficient of Z_4 is not statistically significant when the acreage response equation was estimated by OLS. The 3SLS estimate of this coefficient has a larger magnitude and a higher t-ratio. The numerical impact on acreage response can be calculated from equation (1.1). Since the largest value that Z_4 can have is 100, the maximum impact of the adoption of the tomato harvester is an increase of 51,000 acres for the selected ten counties.[11]

4.49 for Indiana, and 1.05 and 2.65 for Ohio, using the annual data for 1946–65.

Table 2. Derived Elasticities of the Processor Demand for Acreage

Estimation Method	Elasticities with Respect to: Grower Price P_c	Product Price R	Income Z_{10}
3SLS	−1.042	1.531	0.563
OLS	−0.202	8.23	0.490

It is of some importance to investigate whether the adoption of the mechanical harvester affected other structural parameters. Our primary concern is with price elasticity. A cross-product term of $Z_4 \ln P_c$ was introduced to account for this impact. As noted earlier, the extremely high correlation between Z_4 and $Z_4 \ln P_c$ made it inadvisable to carry both variables in the same equation. Results with only the cross-product term included are presented in equation (1.2) in table 1.

Under the present specification, price elasticity, E, at the mean values is decomposable into two components as $E = c_1 + d_1\bar{Z}_4$, where c_1 and d_1 are estimated coefficients of $\ln P_c$ and $Z_4 \ln P_c$, respectively, and $\bar{Z}_4$ is sample mean. Computed in this manner, the two components of the price elasticity are shown in table 3. Results show that the impact of the adoption of the mechanical harvester on price elasticity is, on the average, numerically small.

Since Z_4 has taken the maximum value (100) from 1971 on, it is of greater interest to deter-

[11] Based on the estimated equations in arithmetic form, the maximum impact at the sample means is estimated to be 54,000 acres. In 1972, these ten counties had a total of 158,000 acres contracted.

Table 3. Price Elasticity Components of Acreage Response of Processing Tomatoes

Estimation Method	Elasticity Components: $\ln P_c$	$Z_4 \ln P_c$	Total
	Computed at the Mean Values		
3SLS	1.658	0.034	1.692
OLS	0.883	0.018	0.901
	Computed for 1971		
3SLS	1.658	0.112	1.770
OLS	0.883	0.060	0.943

mine the full impact of this technical change by computing the elasticity components for 1971. This computation is carried through by using the actual value of Z_4 in 1971. The resulting elasticity components are also shown in table 3. It was found that the maximum effects of mechanizing harvesting on the growers' response to price changes generally appear to be small. Full mechanization in harvesting would raise the price elasticity by 6% of the total price elasticity under 3SLS and 7% by OLS.

Concluding Remarks

Results show that the 3SLS estimates of structural coefficients were, in general, more plausible than OLS estimates. In particular, the OLS estimates of the grower price coefficients were consistently lower in magnitude than the 3SLS estimates.

Estimated acreage response and demand elasticities were found to be sensitive to estimation method. The OLS estimates always resulted in a smaller elasticity in absolute magnitude than those estimated by 3SLS. Acreage response was shown to be price elastic by 3SLS but inelastic by OLS. Since for the last twenty years, tomato acreage has increased drastically in California, while it declined rapidly in other states, one would expect an elastic acreage response to price changes. This supposition is supported by the results obtained from the 3SLS procedure, but not by the OLS estimates. These results suggest that a competitive market might be appropriate in describing the California tomato economy, even though leadership pricing is commonly exercised.

The adoption of the tomato harvester was found to have a significant impact when the acreage response was estimated by 3SLS. When it has a significant coefficient, the maximum impact of this technological innovation is calculated to be an increase of 51,000 acres for the selected ten counties. Results also show that the impact of the adoption of the mechanical harvester on price elasticity is, on the average, numerically small. This may be attributable to the fact that California tomato growers in general have large acreage, and therefore, the purchase of a harvester may represent only a small fraction of their total investment. Furthermore, in a preliminary analysis of the pooled county model, Chern found that growers' price response was very high even before the harvester was introduced. Thus, additional price sensitivity induced by the adoption of the harvester is unlikely to be significant relative to the existing level of price response.

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Estimation of Demand for Transportation of Agricultural Commodities

Walter Miklius, Kenneth L. Casavant, and Peter V. Garrod

A logit model is used to estimate the elasticities and cross elasticities for freight transport services. The model is applied to a sample of cherry and apple shipments. The performance of the model in explaining choice of transportation method is highly satisfactory. Estimated coefficients, with one exception, have expected signs and are statistically significant.

Key words: apples, cherries, logit, transportation.

A knowledge of demand of transport services is essential for regulatory as well as management purposes. A recent report notes that one of the principal activities of the Interstate Commerce Commission is to allocate traffic among the different transport modes. Since it lacks the power to issue quotas, it has to do this through the exercise of its power over rates. This, in turn, requires the knowledge of elasticities and cross elasticities of demand for transport service of each mode not only with respect to rates but also with respect to various quality of service characteristics (Task Force on Railroad Productivity, p. 190).

The same report provides an illustration for the need of similar information for management purposes. It recommends that railroads operate shorter trains on more frequent schedules as a means of reducing transit time and its variance. It asserts that the demand is responsive to improvement of service, i.e., more frequent train schedules will generate new traffic presumably more than offsetting high costs (pp. 300–306). Evaluation of this recommendation would require empirical estimates of the elasticity of demand for rail transportation with respect to freight rates, transit time, and its variance.

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Decisions such as these affect not only the financial position of carriers but also incomes of producers of commodities transported and the regional specialization in production. These effects are particularly important in agriculture since agricultural commodities typically move longer distances to the markets and the cost of transportation accounts for a larger percentage of the value of commodity at destination.

Several past attempts at empirical estimation of freight-transport demand functions ran into conceptual, data, and estimation problems (Benishay and Whitaker, Limmer, Miklius, Perle, Sloss). In recent years, however, considerable progress has been made in estimating the demand for urban transport services. Here, the logit model was found to provide the most satisfactory general approach. In this paper we apply the logit model to estimate the elasticities and cross elasticities of demand with respect to prices and the quality of service characteristics of the transport modes.

Adoption of this model for estimating the demand for freight-transport services is discussed in the next section. More complete discussion of the model is available (Miklius and Casavant), and an extensive bibliography is presented by McFadden (1974). The model was applied to two sets of data—a sample of cherry shipments from Washington, Oregon, and Montana and a sample of apple shipments from Washington. The selection of variables is discussed and the empirical results are reported in the two sections that follow. The

sources and nature of data used are described in the appendix.

Cherries were selected because of their high perishability. It was expected that the quality of service, such as the transit time, would be a major factor in selection of the transport mode. Apples, on the other hand, are storable for longer periods of time, and, therefore, the selection of transport mode for their shipments should be more responsive to the differences in transport charges.

The Model

Each firm is faced with a large number of decisions. For the purpose at hand, however, we are mainly interested in a set of purchasing decisions. The reason for the focus on purchasing rather than sales decisions is the predominance of the "FOB shipping point" type of sale, in which the choice of the transport mode rests with the buyer rather than the seller.[1]

For each individual transaction, the four following decisions have to be made by the buyer: whether or not to purchase some of the commodity, what quantity, from what production area or marketing center, and what transport mode to use for shipment. The analysis of the complete decision process is beyond the scope of the present study. However, if buyers' decisions could be assumed to follow the sequence indicated, we could examine the choice of transport mode independently of other decisions. This is equivalent to an implicit assumption that the decision on whether or not to purchase a particular commodity, the size of shipment, and its origin are not affected by performance characteristics (i.e., freight rates, transit time, etc.) of the transport modes.[2]

The logit model has been modified to handle choices among unranked alternatives (McFadden 1968). The decisions to purchase from different production areas, therefore, could be analyzed concurrently with the choices of transport mode. For this initial effort, however, we have limited our analysis to the choices of transport mode.

The essence of the approach is as follows. For each shipment, the buyer is assumed to be faced with a set of mutually exclusive choices, which may include truck, rail, piggyback, and air. Examination of variables influencing these choices allows an estimation of probability that for a given shipment the buyer will make a particular choice. This, in turn, allows statements analogous to ordinary elasticity of demand statements to be made. The problem is to estimate the relationship between the specified explanatory variables and the choice made. For estimation of the demand for freight transport services the logit model could be specified as follows:

$$\log[p/(1-p)] = \alpha + \beta_{1i}C_i - \beta_{1j}C_j + \beta_{2i}T_i - \beta_{2j}T_j + \beta_{3i}VT_i - \beta_{3j}VT_j + \sum_{k=1}^{t}\gamma_K s_K,$$

where the dependent variable is known as "the logit" corresponding to the odds ratio in favor of mode i, C_i and C_j are the freight charges for each competing transport mode, T_i and T_j are their transit times, VT_i and VT_j are their variance of transit times, and s_K is the "kth" shipment, buyer, or seller characteristics considered relevant to the choice of transport mode.

The above model enables us to infer the choice of transport mode from the data on performance attributes of each mode and characteristics of shipments. The model can accommodate any number of alternative choices. The shipments by air and piggyback, however, still account for a relatively small proportion of all shipments, and none were selected in the sample used for estimation. The problem, therefore, was reduced to a binary choice: truck versus rail.

Selection of Variables

Although the choice of variables was affected by data availability, each selected variable has some a priori causal basis.

The rail and truck freight charges are used as two separate variables. Expected signs are those of normal price variables, i.e., the probability that a given transport mode will be chosen is negatively correlated with its own freight charge and positively with the freight charge of the competing mode.

The transit time refers to the promised rather than actual transit time, and it is usually

[1] According to the 1972 Northwest cherry crop survey, the FOB sales made up 87% of the cherry volume. Similarly, 91.5% of the total volume of apples in 1969–70 were sold on an FOB basis (Podany, Bohall, and Pearrow, p. 32).

[2] A somewhat similar problem is encountered in urban transport demand studies because of interdependence between the decision regarding choice of transport mode and the choice of location of home and choice of car ownership. This difficulty is avoided by specifying that the study is concerned with the decisions made after the home location and car ownership are already established.

quoted in days rather than hours, e.g., "third morning delivery," "fourth morning delivery." The expected signs of the transit time variables are determined by a number of factors that depend on the nature of the commodity being shipped. For a highly perishable commodity, where costs associated with time in transit are high, the probability that a particular mode is chosen is expected to be negatively correlated with its own transit time and positively correlated with the transit time of competing modes.

For readily storable commodities, the probability that a given mode will be selected may be either negatively or positively correlated with its own transit time. For shipments into inventory of batch- (or seasonally) produced commodities, in absence of unpredictable shifts in demand for commodity, the expected sign would be positive since the transit time is merely a substitute for the time in inventory. The buyer would choose the slower mode, *ceteris paribus,* as shipping charges implicitly incorporate costs of storage that would be a direct cost to the buyer if a faster mode was chosen. With unpredictable shifts in demand for commodity the sign may be negative, i.e., a buyer would prefer faster transit time mode if the value of loss function due to stockout exceeds the difference in freight charges. Furthermore, inventories could be held either by buyers or by sellers. Holding specialized inventories at shipping points is probably cheaper. Thus, a buyer could reduce his inventory holdings, thereby increasing the probability of a stockout and the probability of shipping by faster mode. The observed signs of the transit time coefficient would depend on the strength of the two opposite effects.

The dependability of transit time is widely regarded as an important determinant of model choice (Woods and Domenchich, pp. 25–34). Its quantification, however, proved to be somewhat of a problem. Although actual transit time for each cherry shipment was available, the number of observations to different destinations was not sufficient to test for the differences in reliability of delivery time. In addition, there may be a difference between actual variability of transit time and the variability perceived by the shippers (Bayliss, pp. 30–32). Thus, for lack of any suitable alternative, the variability of transit time had to be left out in estimation of the model for cherry shipments.

In the sample of apple shipments, the identity of the buyer of each shipment was known. This allowed us to conduct a supplementary survey of buyers who asked two hypothetical questions. (*a*) Suppose that you shipped 100 truckloads of apples. How many of these shipments would arrive on the promised day, one day late, two days late, etc.? (*b*) Suppose that you shipped 100 rail carloads of apples. How many of these shipments would you expect to arrive on the promised day, etc.? The responses to these questions may be interpreted as the subjective probability functions, and the mean of each function could be used as a proxy variable for the value of truck and rail transit time variability, respectively. This procedure, however, assumes a linear loss function; i.e., the value of a two-day delay is assumed to be equal to the sum of the values of two one-day delays. To avoid this linearity, the subjective probability functions could be weighted by square of the delay. Both variables, identified as "expected delay" and "expected cost of delay," were used in alternative estimations of the model.

Two additional variables were added in estimation of the model for cherry shipments. The value of commodity variable was included to account for a possible shift of demand for transport services during the shipping season. One would expect the value of transit time to be positively correlated with the value of commodity for several reasons. First, since one of the costs involved in a longer time in transit is interest, it depends on the value of the shipment (Meyer et al., p. 192). Second, the price changes during the shipping season follow a typical pattern of starting with a relatively high price at the beginning of the season, followed by a rapid decrease at first and a more gradual decrease until some minimum is reached with prices rising gradually thereafter until the end of the season. The probability of a sharp drop in prices, therefore, is greater at the beginning of the season when the prices are higher. For both of these reasons, one would expect the willingness of buyers to pay higher freight rates in exchange for faster transit time to be correlated with value of commodity.

The second variable, the age of pack, was added to serve as a proxy variable for the quality of cherries prior to shipment. It is expected that cherries that have been in storage prior to shipment would move, other things being equal, by a transport mode with a shorter transit time.

Table 1. Elasticities and Cross Elasticities of Demand for Rail and Truck Transportation of Cherries

Variable	Coefficient	t-ratio	Elasticity or Cross Elasticity for Rail Service	Elasticity or Cross Elasticity for Truck Service
Rail freight charges	−0.0161	5.6701	−2.8696	4.1466
Truck freight charges	0.0040	2.8060	1.1484	−1.6594
Rail transit time	−2.3438	6.6594	−5.5678	8.0454
Truck transit time	2.7822	4.9945	4.1194	−5.9524
Age of pack	−0.3775	5.5102	−0.4660	0.6732
Gross value	−0.0006	5.0270	−1.3133	1.9008
Constant	6.4788	6.6264	—	—

Empirical Results

The results of cherry shipments are shown in table 1. The reported coefficients are the maximum likelihood parameter estimates with respect to the log of the odds ratio in favor of rail transport, derived by an available computer program (Nerlove and Press). Since the model is symmetrical, the coefficients with respect to the odds ratio in favor of truck transport would have the same values but the opposite signs (Theil). The estimated elasticities and cross elasticities are analogous to the ordinary elasticity of demand and can be easily derived from the estimated coefficients. The elasticity of demand with respect to the ith variable is defined as $\frac{dQ}{dX_i}\frac{X_i}{Q}$. This can be expressed in terms of the elasticity of probability by writing $\frac{dQ}{Q}\frac{X_i}{dX_i} = \frac{d(pS)}{pS}\frac{X_i}{dX_i} = \frac{dp}{dX_i}\frac{X_i}{p}$, where p is the probability and S the total number of shipments. It can be shown that $\frac{dp}{dX_i}\frac{X_i}{p} = \beta_i X_i(1-p)$, where β_i is the estimated logit coefficient.[3] The estimated elasticities are reported in the last two columns of table 1.

The statistical results are very encouraging. All coefficients have a priori expected signs and are significant at the 1% level using the normal approximation.[4] To assess the overall explanatory power of the model, the likelihood-ratio test was used to test the hypothesis that all estimated coefficients are equal to zero. The χ^2 was equal to 301.42, above the critical value of 18.55 for six degrees of freedom. Thus, the hypothesis that the parameters are equal to 0 was rejected. Furthermore, the elasticity estimates are plausible. The demand for both rail and truck transport service is relatively elastic not only with respect to its own transit time and freight charges but also with respect to those of the competing mode. As could be expected for a highly perishable commodity like cherries, the choice of transport mode is much more sensitive to the transit time than to freight charges.

The results for apple shipments are reported in tables 2 and 3. In the two alternative estimations of the model, the "expected delay" and the "expected cost of delay" were used respectively as the variable for the variability of transit time. However, there is very little difference in the results between two specifications of the model. In both cases, the freight-charge coefficients have expected signs and are highly significant. The variability of transit time coefficients also have expected signs and are significant at the 5% level using the normal approximation.

The rail transit time coefficient has a positive sign and is significant at the 5% level, indicating that buyers are indeed substituting transit time for the time in inventory. The truck transit time coefficient is not statistically significant. The lack of significance is probably due to specification bias, i.e., some variables affecting model choice were not included

[3] This expression is readily obtained in the binary case by taking the total derivative of the logit equation, holding all X but X_i constant. The logit equation and its derivative are

$$p/(1-p) = e^{\alpha + \Sigma \beta_j X_j}$$

$$dp - (1-p)^2 \beta_i dX_i \, e^{\alpha + \Sigma \beta_j X_j} = 0.$$

Solving for the elasticity yields $(dp\, X_i)/(dX_i\, p) = \beta_i X_i(1-p)$. The estimated point elasticity of Q with respect to X_i is then $\beta_i \overline{X}_i(1-\overline{p})$, where $\overline{X}_i$ is the sample mean of X_i and $\overline{p}$ is the observed proportion of the shipments using the mode in question.

[4] The use of the normal approximation is justified by the large number of observations (516).

Table 2. Elasticities and Cross Elasticities of Demand for Rail and Truck Transportation of Apples (Transit Time = Expected Delay)

Variable	Coefficient	*t*-ratio	Elasticity or Cross Elasticity for Rail Service	Elasticity or Cross Elasticity for Truck Service
Rail freight charges	−5.9088	6.7364	−12.5702	3.5455
Truck freight charges	4.7388	6.7960	10.0454	−6.4396
Rail transit time	0.7106	2.1924	2.7252	−0.7686
Truck transit time	−0.4670	0.7559	−1.1759	0.3317
Expected delay—rail	−0.7682	2.7636	−0.5272	0.1811
Expected delay—truck	9.9354	1.6899	0.1778	−0.0501
Constant	0.4460	0.2637	—	—

in the model. For example, truck transportation may have been chosen because it is more flexible. Unlike railroads, truckers are not constrained either to the scheduling or to fixed point pickup and delivery of trains. The buyer may have been willing to pay higher charges for this flexibility.

There also may be a feedback effect between choice of transport mode and size of shipment; the quantity a buyer wishes to ship may determine the mode and the mode chosen may limit the size of the shipment. Clearly, the capacity of a rail car is greater than that of a truck. The efficiency of trucks for transportation of small lots, however, may not be reflected in freight charge differences.

The overall explanatory power of the model is still satisfactory. The χ^2 is equal to 290.19, again way above the critical value of 18.55.

Conclusions

The purpose of the research effort, the results of which are reported in this paper, was to use the logit model to estimate the elasticities and cross elasticities for freight transport services. The model was applied to a sample of cherry shipments and a sample of apple shipments moving long distances to their markets.

The results for cherry shipments are rather encouraging. All estimated coefficients had a priori expected signs and were highly significant. Overall, the performance of the model in explaining modal choices was highly satisfactory.

The results for apple shipments are less satisfactory. It is difficult to provide a satisfactory explanation for the positive sign of the rail transit time coefficient and statistically insignificant truck transit time coefficient. Incomplete specification of the model is one possible explanation. The missing interrelationship between inventory and transport mode decisions is another. Inventory considerations as well as the decision where to buy may be closely interrelated with the choice of the transport mode.

Testing of this hypothesis would require development of the model that would cover the complete decision process rather than concentrating on the choice of the transport mode alone. While such a model could be developed, its testing would require considerable data collection effort. However, before this research effort is undertaken, it may be advisable to apply the logit model to shipments of other commodities. After all, by their nature, the estimates obtained in this study are specific, for they are functions of the sample

Table 3. Elasticities and Cross Elasticities of Demand for Rail and Truck Transportation of Applies (Transit Time = Expected Cost of Delay)

Variable	Coefficient	*t*-ratio	Elasticity or Cross Elasticity for Rail Service	Elasticity or Cross Elasticity for Truck Service
Rail freight charges	−5.8368	6.8416	−12.4170	3.5022
Truck freight charges	4.6846	6.7014	9.9308	−2.8010
Rail transit time	0.7274	2.2614	2.7896	−0.7868
Truck transit time	−0.4790	0.7801	−1.2063	0.3402
Expected cost of delay—rail	−0.3030	2.6895	−0.4413	0.1245
Expected cost of delay—truck	0.5240	1.9315	0.1697	−0.0479
Constant	−0.6632	0.3979	—	—

data. Repeated applications of the model would provide a further evaluation and guidance for the future research work.

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Appendix

Nature and Sources of Data

The main source of data on cherry shipments was the survey conducted by the Washington State Department of Agriculture. The survey covered the 1972 shipping season, which started on June 13 and continued through August 2, a total of fifty-one days.

In the survey a cross section of shippers was selected, and all shipments of those selected were included in the sample. The survey supplied information on 1,374 shipments accounting for 9,455 tons or approximately one-fourth of the crop grown in the three Northwest states.

The total sample, however, could not be used for estimation of the model. Shipments lacking information on one or more variables were omitted from the sample. First, age of pack was not reported for 536 shipments. Second, rail freight rates were not available to destinations west of Denver since all shipments move by truck. Third, shipments to Canadian destinations had to be excluded because of the difficulties in obtaining truck freight charges. As a result, the subsample used for estimation of the model contained 516 observations. The distribution of shipments by transport mode in the subsample was as follows. There were 305 shipments by rail (59.1%) and 211 shipments by truck (40.9%). The survey provided no information on freight charges. The truck freight charges were obtained from shippers and truckers, while the rail freight charges were supplied by the Burlington Northern, Inc.

The main source of data on apple shipments was provided by the survey conducted by the Department of Agricultural Economics, Washington State University. Although the survey was conducted in 1974, it covered the 1972 shipping season. The selection of 1972 shipping season was dictated by the shortages of rail and truck capacity beginning with the "fuel crisis" of 1973. In later years, choice of the transport mode was dictated by first availability of equipment. This, in turn, violates the basic assumption of the model that a decisionmaker has a choice of alternative modes.

For the survey apple shippers located in the Yakima, Washington, area were stratified by size, and two large, three medium, and two small shippers were drawn randomly. Then every tenth shipment was selected from their records.

This procedure produced a total sample of 821 observations. Again shipments to destinations west of Denver and shipments to buyers who did not respond to our

supplementary survey of buyers described above were excluded. The subsample used for estimation of the model included 577 shipments. The distribution of shipments by transport mode in the subsample was as follows. There were 127 shipments by rail (22%) and 450 shipments by truck (78%). The truck freight charges were obtained from shippers and truckers and the rail freight charges were supplied by the Burlington Northern, Inc.

Grain Marketing and Transportation Interdependencies: A National Model

Jerry A. Fedeler and Earl O. Heady

Ten specifications of a linear programming model are developed to jointly select the least cost locations of grain production and interregional grain transportation in the United States. Analyses are based on 1980 demand projections for wheat, soybeans, and feed grains. Seven model options represent alternative transportation systems and include alternative cost estimates for railroad and barge transportation. Three other options are specified to analyze interdependencies between grain exports and transportation. Results suggest that choice of transportation mode and grain flows are sensitive to transportation cost changes and the distribution of exports among ports but the location of grain production is not.

Key words: barges, grain exports, grain production, grain transportation, railroads, trucks.

Grain exports at unprecedented levels in 1972 placed severe pressures on the grain transportation network. The event indicated the dependence of farmers, grain elevator managers, processors, exporters, and other groups on the transportation system. In 1975 there are rumors of large U.S. grain exports. Hence, the grain transportation system may face comparable pressures in the future.

The widespread transportation shortages in 1972 vividly illustrated that grain transportation depends on a national system, even though it is comprised of smaller, interlinked components. This national network can be viewed as an interregional competition system, but few researchers have empirically developed such systems except for studies of industrial plant location.[1] Too frequently only part of the entire national system has been considered in analyses that omit major routes, modes, grains, or areas. The most comprehensive of earlier models are those by Leath and Blakley and the associated models by Schnake and Franzmann. Their models are national, include wheat, feed grains, and soybeans, and utilize rail, water, and highway transportation. Schnake and Franzmann compare a cost-of-service transportation rate structure with actual rates. They summarize national transportation costs but unfortunately do not give either cost or traffic volume by transportation mode.

This paper describes the methods and results of an interregional grain transportation study within the United States for 1980. The emphasis is on choice among transportation modes, grain movements, and production regions.[2] The analysis projects regional demands and determines the least cost configuration of transportation and production under six alternative transportation systems, two alternative distributions of exports among port regions, and one alternative level of exports (table 1).[3]

Grains included are wheat, soybeans, corn, oats, barley, and grain sorghums; the last four are aggregated into one commodity, feed grains, on the basis of their feed values. In addition to these grains, cotton is included because it competes with grains for cropland

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[1] Among the interregional studies are those by Free; Schnake and Franzmann; Leath and Blakely; and Wright. These are all national in scope, have fixed regional grain supplies, and emphasize the location of industrial grain-processing plants.

[2] Past studies concentrating on the location of grain production have not considered changes in transportation activities. Several examples of these models are in Heady, Mayer, and Madsen.

[3] Transportation costs in the model are designed to represent transportation operators' costs, not the market price of transportation services, plus grain elevator loading and unloading costs. Therefore, using 1972 as the base year does not introduce unusual costs stemming from abnormal marketings in 1972.

Table 1. Alternative Model Specifications

Option[a]	
1	The base model (has an estimated 1972 interregional transportation cost structure with demands and yields projected for normal or average conditions for 1980 based on past trends)
2	A rail system with shipments in 50-car units (is incorporated to represent a transportation network including a multicar system, i.e., a rail system with large individual shipments)
3	A 10% increase in all rail costs
4	A 20% increase in all rail costs
5	A 10% increase in all barge costs
6	A 20% increase in all barge costs
7	An alternative single-car rail transport system (reducing the variable and increasing the fixed cost of rail transportation)
8	A reassignment of 10% of the Gulf export demands to Seattle (to analyze redistribution of the traditional demands for exports among ports at the Gulf and the Northwest coast)
9	A reassignment of 25% of the Gulf export demands to Seattle
10[b]	A 25% increase in all grain exports

[a] Options 2 through 10 are identical to option 1, except for the changes indicated in the table.
[b] Additional exports in option 10 are assumed to be exported as unprocessed, whole grain, and the percentage distribution among port regions is the same as for option 1.

and cottonseed is a major substitute for soybeans.

Methods and Procedure

Domestic and export demands are first projected to 1980 for each crop.[4] A linear programming model determines the least cost transportation modes, grain shipments, and production location for each crop. Seventy-eight domestic and export demand regions and 152 producing regions are delineated for the forty-eight contiguous states.

The Model

The variables in the linear programming model represent interregional grain transportation processes and regional grain and cotton production activities.[5] The objective function is

$$APTC = \sum_k \sum_i C_i^k X_i^k + \sum_k \sum_i \sum_j \sum_t P_{ijt}^k T_{ijt}^k,$$

where $APTC$ = annual production and transportation costs, i = producing region index, k = crop index, C_i^k = all costs, except land, of producing crop k in region i, t = time period index, X_i^k = the number of acres of crop k produced in region i, P_{ijt}^k = the cost of transporting one ton of crop k in time period t from producing region i to consuming region j, and T_{ijt}^k = the number of tons of crop k transported in time period t from producing region i to consuming region j. Annual production and transportation costs are minimized subject to regional land constraints identified in a previous study (Heady, Mayer, and Madsen, p. 115).[6] In addition, acreage bounds are specified as a substitute for other constraints (including seasonality of labor, risk, conservation practices, and disease control) that discourage crop production specialization. These bounds are not totally restrictive but permit 1980 crop acreages to range at least from 20% below to 20% above 1969 actual acreages, except upper limits on soybean acreages are restricted to 50% of the available land or 1969 actual acreages, whichever is larger (Fedeler, Heady, and Koo, pp. 60–61).[7] The amount of each crop shipped from a region is constrained to be no more than the regional production.

Feed grains, soybeans, and wheat shipped into a consuming region during each time period are required to be no less than the consuming region's corresponding demand. Annual demands for feed grains and soybeans are allocated to two periods, December through March and April through November, because the Missouri River, the Upper Mississippi River, and the Great Lakes are not navigable in winter. Regional wheat demands remain on an annual basis to lower computational costs.[8] The model requires cotton production to satisfy a national cotton lint demand and the

[4] All demands estimated are fixed-point estimates of the quantity demanded, given the underlying parameters of the projections.

[5] The crop yields and production costs are those for the typical farm structure described in detail elsewhere (Sonka, pp. 79–116).

[6] In the earlier model, the major grain-producing areas are divided into 150 producing regions by aggregating counties with relatively homogeneous production characteristics. The two additional regions, 151 and 152, stem from dividing region 71 of the former study into three regions, so that one of them corresponds to the area intensively analyzed elsewhere (Baumel et al.).

[7] Because nearly all available land is utilized in option 10, the upper bounds for feed grains and wheat in that option are adjusted upward for some regions so that the sum of the lower limits for cotton and soybeans plus the upper limits for feed grains and wheat is at least as great as the total land available in each region. A comprehensive analysis shows that very few of these are significantly restrictive (Fedeler, Heady, and Koo, pp. 84–88).

[8] Preferably, two demand periods would be used for wheat; however, this simplification may not be overly restrictive because timing of the wheat harvest readily permits shipments by water after harvest and before winter, allowing it to be stored near either origins or destinations, and water transportation is relatively less important for wheat. In 1972, for example, the quantity of wheat shipped by rail was 7.2 times that shipped by water whereas the ratio was 1.2 for soybeans and 2.8 for feed grains (Fedeler, Heady, and Koo, pp. 174, 178).

resulting cottonseed in excess of seed requirements is used to partially satisfy an aggregate demand for soybean and cottonseed meal. The aggregation is based on their relative feed values and the balance of the aggregate demand is met by soybeans. The cottonseed meal is regionally distributed so that it does not distort the regional distribution of demands by soybean processors.

Demands

Total national demands for 1980 are projected on the basis of 226.9 million U.S. population. Demands for livestock feed are derived from projected per capita demands for livestock products (beef, pork, broilers, sheep, turkey, milk, and eggs) adjusted for net foreign trade and direct grain demands for horses, mules, and other livestock. Demand projections include industrial uses of grain such as cereal, dry processing, wet processing, flour, alcohol, malt, etc. Per capita demands are based on commodity price indexes, real income per capita, and time. Two levels of grain exports are considered to surmount unpredictable events surrounding changes in foreign trade policy. For options 1 through 9, exports are 27.5 million tons of corn equivalent feed grains, 22.4 million tons of wheat and wheat flour equivalent, 31.2 million tons of soybeans and soybean meal equivalent, and 2.1 million bales of cotton lint. Feedgrain, wheat, and soybean exports are 25% greater in option 10.[9]

Transportation Costs

The model utilizes transportation costs between producing and consuming regions by crop and time period. Transportation costs in option 1 are for rail movements in single hopper cars; highway movements in five-axle, tractor-semitrailer trucks; barge movements in 195′ × 35′ covered hopper barges, except on the Columbia and Snake rivers where costs are estimated for 250′ × 42′ barges; and ship movements on the Great Lakes. Combinations of transportation modes are used when they are the least costly method. In option 1, single-car rail costs for a route are $RC_g = \sum_{i=1}^{4} k_{gi}M_i + 1/2(T_{go} + T_{gd})$, where RC_g is the rail cost for grain g, k_{gi} is the mileage coefficient for grain g and rail cost territory i, M_i is mileage in territory i, T_{go} is terminal cost for the origin, and T_{gd} is terminal cost for the destination. Territories for computing rail costs are the Official (including New England), Southern, Western (excluding Mountain Pacific), and Mountain Pacific. Values for k_{gi}, T_{go}, and T_{gd} for 1972 are computed by inflating corresponding published values 24% for price and wage increases (Interstate Commerce Commission, July 1972). Published variable costs are used because they are broadly defined as "costs, which over the long-run period, . . . have been found to be variable with traffic changes" (Interstate Commerce Commission, July 1972, p. 4) and fixed costs are allocated arbitrarily on the basis of ton-miles, placing an excessively large burden on heavy cargo like grain.

The fifty-car costs for option 2 are derived by adjusting single-car costs using the procedure developed in the study by Baumel et al. because there are no comparable Interstate Commerce Commission (ICC) published costs for multicar shipments. The alternative rail costs in option 7 have 50% greater terminal costs and 10% lower mileage costs than the single-car costs in option 1. This option is included to show the effects of biases some industry personnel claim are built into the published costs.

Barging costs for a given route are $BC_g = \sum_{i=1}^{n} (t_i^1 T_g + t_i^e) M_i + K$, where BC_g is barge load cost for grain g, n is the number of river sections traveled, t_i^1 is towing cost per ton-mile for a loaded barge for river section i, T_g is tons (actual or minimum required for the towing charge) of grain g, t_i^e is return trip towing cost per mile for an empty barge for river section i, M_i is miles traveled on river section i, and K is the sum of other barging costs. Included in K are capital ownership cost, insurance, maintenance, repair, cleaning, administration, overhead, and tax costs for the barge, and total round trip switching, fleeting, and harbor costs. Most of the cost variables are unique for specific river sections, origins, and destinations and are in Fedeler, Heady, and Koo.[10] Water systems included are the Mississippi River and its tributaries, the Gulf of Mexico, the Warrior-Tombigbee river system, and the Columbia and Snake rivers. The estimated cost of shipping from Duluth to Buf-

[9] The derivation of demands by regions and time periods and additional details of the demand projections can be found in Fedeler, Heady, and Koo.

[10] Estimates for water transportation costs benefited substantially from data supplied by industry representatives.

falo is 15¢ per bushel. Other potential Great Lakes shipping routes were eliminated prior to solving the linear program because of high cost vis-à-vis other transport modes.

Trucking costs for a given route are $TC = 1.6 \sum_{i=1}^{8} (C_v^h H + C_v^m M)\, d_i F_i + 2/3 C_v^h$, where TC is truckload cost, C_v^h is the hourly cost, H is hours per one-way trip, C_v^m is mileage cost, M is one-way mileage, d_i is percentage of miles in truck cost region i, and F_i is an adjustment factor for region i. The costs of fuel, oil, tires, maintenance, and repairs are allocated to distance and the capital cost of ownership, license fees, insurance, highway use tax, overhead, and driver's wages are allocated to time. For the Midwest, C_v^h is \$8.70, C_v^m is 11.035¢, and F_i is 1. For seven other regions (New England, Middle Atlantic, Central, Southern, Southwestern, Rocky Mountain, and Pacific Coast), F_i is the ratio of the region's to the Midwest's line haul costs for moving 20,000 to 29,999 pounds 100 to 124 miles (Interstate Commerce Commission, May 1972). The coefficient 1.6 accounts for an assumed backhaul for 40% of the return trips and the last term represents the estimated truck (not grain elevator) cost of forty minutes per trip for loading and unloading.

Transportation cost coefficients in the objective function of the model are the sum of the carriers' costs and elevator loading and unloading costs adopted from table 3 in Schienbein and Vosloh. Transportation costs for feed grains originating in a producing region are the weighted averages for the individual grains. The weights are the relative tonnage of each grain sold from farms for the state containing the producing region.

Results and Implications

The model's solutions provide transportation costs and interregional shipments by grain and transportation mode for each option. National results are emphasized because they depict overall differences among options and have national implications, but this does not detract from the importance of results for localities.

Transportation

The quantities of grain hauled interregionally by individual transportation modes vary substantially among the options (table 2).[11] Multimodal hauls are either rail-water or truck-water combinations. Rail-water shipments are surprisingly large and exceed truck-water tonnages in options 2, 5, 6, and 10. In option 1, 6.3 million tons are transported by rail-water and 7.0 million tons by truck-water. Twenty-one percent shipped by water in option 1 is moved in conjunction with rail. Current multimodal data are not available but most are undoubtedly truck-water. In reality, obtaining significant increases in rail-water shipments through normal rate adjustments is question-

[11] In the model, all grain is shipped from the producing regions to consuming regions. No transportation cost is charged for intraregional shipments, i.e., transfers of grain from a producing region to the consuming region containing part or all of the producing region. This is justified because much grain is utilized locally, including on farms where grown. Consequently, interregional shipments are defined as grain moved out of the consuming region where produced.

Table 2. Interregional Grain Shipments

Option	Rail (1,000 tons)	Water[a] (1,000 tons)	Truck	Multi-modal	Total[b]
1. Single-car	116,741	30,280	6,975	13,266	140,730
2. 50-car	121,049	24,372	2,789	7,070	141,140
3. 10% rail	113,012	33,397	11,405	17,385	140,429
4. 20% rail	107,976	38,771	14,752	20,914	140,585
5. 10% barge	120,556	26,339	2,991	9,223	140,663
6. 20% barge	121,859	24,255	2,568	7,884	140,798
7. Alternative single-car	111,705	30,490	11,418	12,917	140,696
8. 10% Gulf-Seattle	118,364	26,756	5,425	9,921	140,624
9. 25% Gulf-Seattle	120,708	22,390	4,519	6,803	140,814
10. 25% export	127,954	35,361	8,451	18,089	153,677

[a] Ships are assumed to be used for the Great Lakes and the 1,000 tons they haul are 199 in option 2, none in option 7, 801 in option 10, and 883 in options 1, 3, 4, 5, 6, 8, and 9. Barges carry all other water shipments.
[b] Total shipments equal the sum of rail, water, and truck less multimodal shipments because a ton transported by a combination of modes is reported for each individual mode.

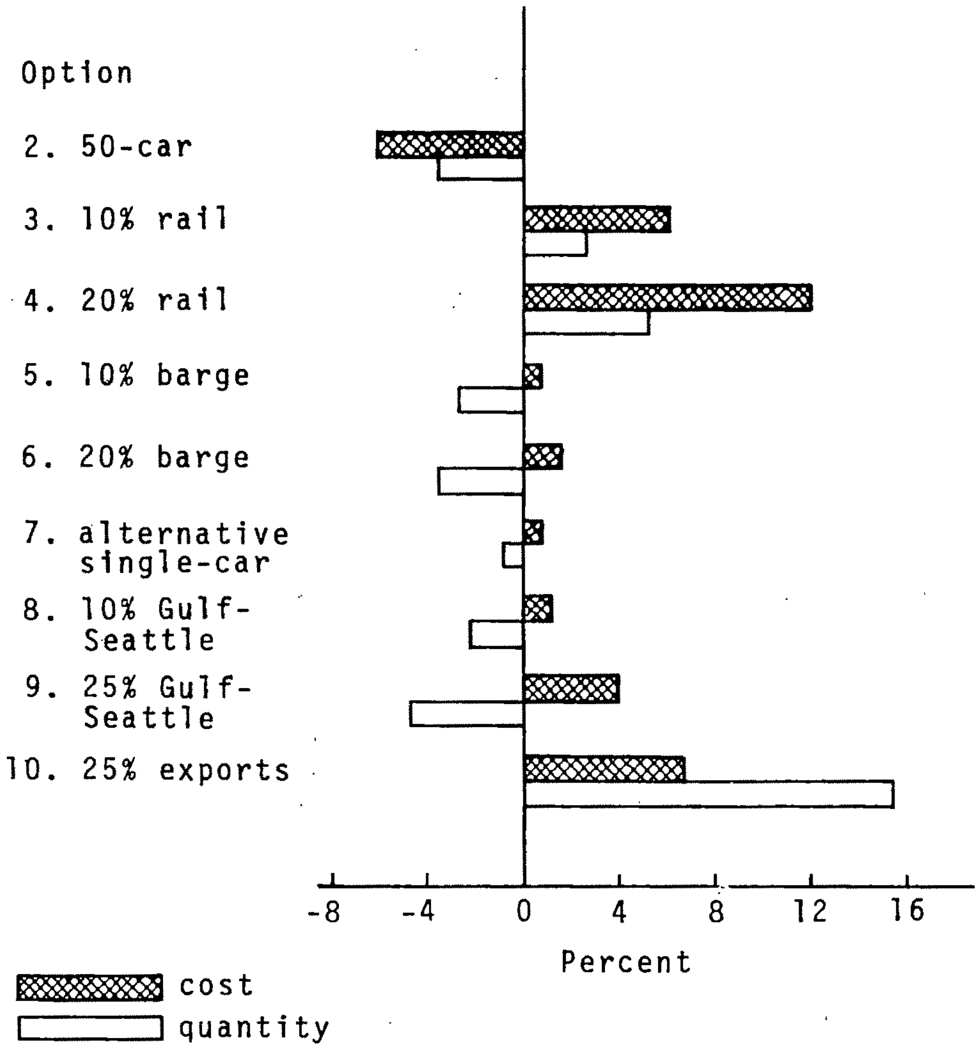

Figure 1. Percentage change from option 1 in interregional grain transportation costs and sum of rail, water, and truck shipments

able because it would likely be unprofitable for individual carriers. Truckers are reluctant to turn over to railroads hauls from producing areas to barging points and railroads prefer to capture an entire haul all the way to final destination rather than surrender part of it to barges. Nevertheless, for least cost transportation, the results suggest policymakers should review possibilities for increasing rail-barge shipments.

The 6.1% cost decrease in option 2 (figure 1) is equivalent to 56¢ per ton of grain hauled by rail. Because larger volumes would be gathered together at fewer points, assembling them for shipment would likely be more expensive for fifty-car than for single-car rail shipments. But the 6.1% cost reduction of option 2 would more than offset the added assembly cost in localities with relatively heavy outbound shipments per unit area. This conclusion is supported by an analysis of a region by Baumel et al.

Total transportation costs are substantially affected by changes in rail costs but affected little by barge costs changes (figure 1). The largest cost increases, excluding option 10, result from the 10% and 20% increases in rail costs, options 3 and 4. For each 10% increase in rail costs, total transportation costs increase approximately 0.6% for both options 3 and 4. Barging cost increases, options 5 and 6, result in higher transportation costs (figure 1), fewer barge and truck shipments, and more rail shipments (table 2) than in option 1. Two re-

Table 3. Summary of Grain Traffic

	Rail		Inland Waterways	
Year	(Million tons)	(Billion ton-miles)	(Million tons)	(Billion ton-miles)
1971	97	42	24.9	22.7
1972	105	46	32.5	35.4
1973	131	57	32.6	37.1
1980 option 1	117	87	30.3	36.4
1980 option 10	128	91	35.4	43.2

Note: Col. 1, 1971–73, obtained from Interstate Commerce Commission, *Freight Commodity Statistics Class I Railroads*. Col. 2, 1971–73, estimated by multiplying the number of tons by the average haul per ton for grain as reported by the U.S. Dep. of Transportation. Cols. 3 and 4, 1971–73, obtained from U.S. Corps of Engineers.

sults regarding rail and barge cost increases deserve further comment. First, transportation costs, vis-à-vis tons hauled, increase more for rail than for barge cost increases. In option 1, tons hauled by rail are 3.97 times the tons shipped by barge but the increase in transportation costs is 7.11 times larger for a 20% increase in rail costs than for an equal increase in barge costs. Second, grain switches more readily from rail to barge when rail costs increase than from barge to rail when barge costs increase, i.e., both the quantity railroaded and the quantity barged are more responsive to rail cost changes than to equal percentage barge cost changes. When rail costs are increased 20%, the quantity barged increases 28.9%, but when barge costs are increased 20%, the quantity barged decreases only 20.5%. These results occur because multimodal shipments are more common with barges than with rail. The percentage of all tons barged that are part of multimodal shipments is 44 in option 1, 35 in option 4, and 33 in option 6. The comparable percentages for rail are 5 in option 1, 8 in option 4, and 3 in option 6. For a multimodal shipment, when the cost for one mode changes the intermodal transfer costs, the costs associated with other modes remain unchanged. The model selects methods of transportation on the basis of cost for entire routes. Consequently, the impacts of changes in barge costs are smaller than for equal percentage changes in rail costs.

Grain elevator loading and unloading costs among options 1 through 9 range from $239 million in option 2 to $251 million in option 4. The ranking of the options by elevator costs is very similar to their ranking by multimodal shipments (table 2) because of the elevator costs for intermodal transfers. Elevator costs as a percentage of total interregional transportation costs range from 19.9 in option 4 to 22.5 in option 2, and the average for all options is 21.2. Elevator costs are an important part of transportation costs and should be included in grain marketing decisions. If a program for grain reserves is adopted, decisions pertaining to their storage location should include loading and unloading costs.

Compared to tons transported in 1972 and 1973, rail data for the model (table 3) are biased downward because they exclude intraregional shipments and the division of a haul into two shorter ones through the unloading and later reloading of rail cars. Also, shipments occurring because of daily fluctuations, imperfect coordination, and other real world frictions among markets are left out.[12] Taking this bias into account it is likely that tons hauled by rail in 1980 will be at least 20% greater than the interregional shipments resulting from the model. The need for expanded railroad capacity is likely to grow even more rapidly when it is expressed in ton-miles than in tons (table 3). To the extent these results can be used to project the demand for rail, it can be concluded that by 1980 rail capacity will need to be even greater than it was in 1973. If exports are as large as in option 10, as many as 154 million tons (17% more than in 1973) could be railroaded.

Internal grain shipments by water in 1961 were 10.3 million tons and 9.5 billion ton-miles (U.S. Corps of Engineers). By 1972 they had grown to 32.5 million tons and 35.4 billion ton-miles (table 3). Results for water, vis-à-vis rail, are more comparable to reality because grain seldom moves intraregionally by water and rarely is unloaded from and reloaded onto barges. Under assumptions of option 1, it can

[12] If rail costs in the model are lower than actual rates, the model may overestimate interregional grain traffic. But the small variation in total tons shipped interregionally among the first nine options suggests that this bias towards overestimation is minimal.

be concluded that water shipments will stabilize near current levels. But results from options 8, 9, and 10 show that water shipments are closely related to exports. Decisions pertaining to the development of river navigation should carefully consider the level and port distribution of exports.

Interregional Grain Flows

The variation in total interregional shipments among options 1 through 9 is small; the ratio of the greatest, option 2, to the smallest, option 3, is only 1.005. The magnitude of total flows for individual options have limited significance because they depend on the delineation of regions. But the small variation among the options shows that moderate changes in the transportation cost structure and distribution of exports among ports do not significantly change the division between interregional and intraregional shipments. The variation might have been greater if the model had included the choice of location for grain-processing plants. The stability in the location of final demand, however, probably would be similar to that of production unless there were changes in the relationship between the transportation costs for processor inputs (whole grain) and their products.

The constancy of the total flows belies, however, the extent of changes in individual flows. Among the options, the net change in the total number of flows (329 in option 1) is small, but the set of flows selected varies substantially. The complete removal and addition of flows reflects essentially all changes because the magnitudes of flows for the same route in two options are with very few exceptions identical. Comparisons of option 1 with the other options show that option 9 has the greatest change in individual flows with a net increase of only 19 flows resulting from the addition of 114 new flows and the removal of 95 flows that were in option 1. Option 5 has the fewest changes with a net addition of 8 flows resulting from the addition of 38 new flows and the removal of 30 flows that are in option 1. These results suggest that transportation cost and export demand changes are likely to substantially disrupt the configuration of interregional grain flows, while their total quantity remains stable. This is particularly relevant for terminal grain elevators, warehouses, and wholesalers. A good location for grain traders may be undesirable under a different transportation cost structure. Although the flow of grain through an elevator may be stable, the location of those who buy from or sell to the elevator may be sensitive to transportation and export changes.

Total grain exports in option 10 are 20.3 million tons more than in option 1 but interregional flows increase only 12.9 million tons. If production and grain markets are given time to adjust to higher export levels, the increase in interregional transportation requirements is significantly less than the increase in exports.

Production

The variation in national yields, acres utilized, and production costs (excluding returns to land) is small among options 1 through 9. Higher export levels of option 10 require more production (table 4), which is possible within the model by utilizing more land at somewhat lower yields.

Feed-grain, soybean, and wheat production for options 2 through 9 are the same as option 1 in at least 146 of the 152 producing areas. Regional cotton production is identical among options 1 through 9. Complementary to the location of production is the geographical distribution of available land not used for crops. Land not used for crops in option 1 is shown in figure 2. Again it is more important to emphasize the constancy in location of unused land among the options than its location for any single option. The location of available cropland not used for crops in option 1 remains nearly the same for options 2 through 9. The greatest changes in land utilization occur when rail costs are increased 20%, option 4. In that option the area of unused cropland in North Dakota increases 1,066,800 acres. The corresponding increase in cropland utilization that offsets the decline in North Dakota is scattered among Georgia, Ohio, Minnesota, Kansas, and Oklahoma. This million-acre shift represents less than 4% of the 28.3 million unused acres in option 1. Increasing rail

Table 4. Estimated Grain Production

	Feed Grains[a]	Soybeans	Wheat
	(Million tons)		
1973	202[b]	47[b]	51[b]
Options 1–9	229	54	46
Option 10	236	62	52

[a] Corn equivalent units.
[b] Figures obtained from the U.S. Dep. of Agriculture.

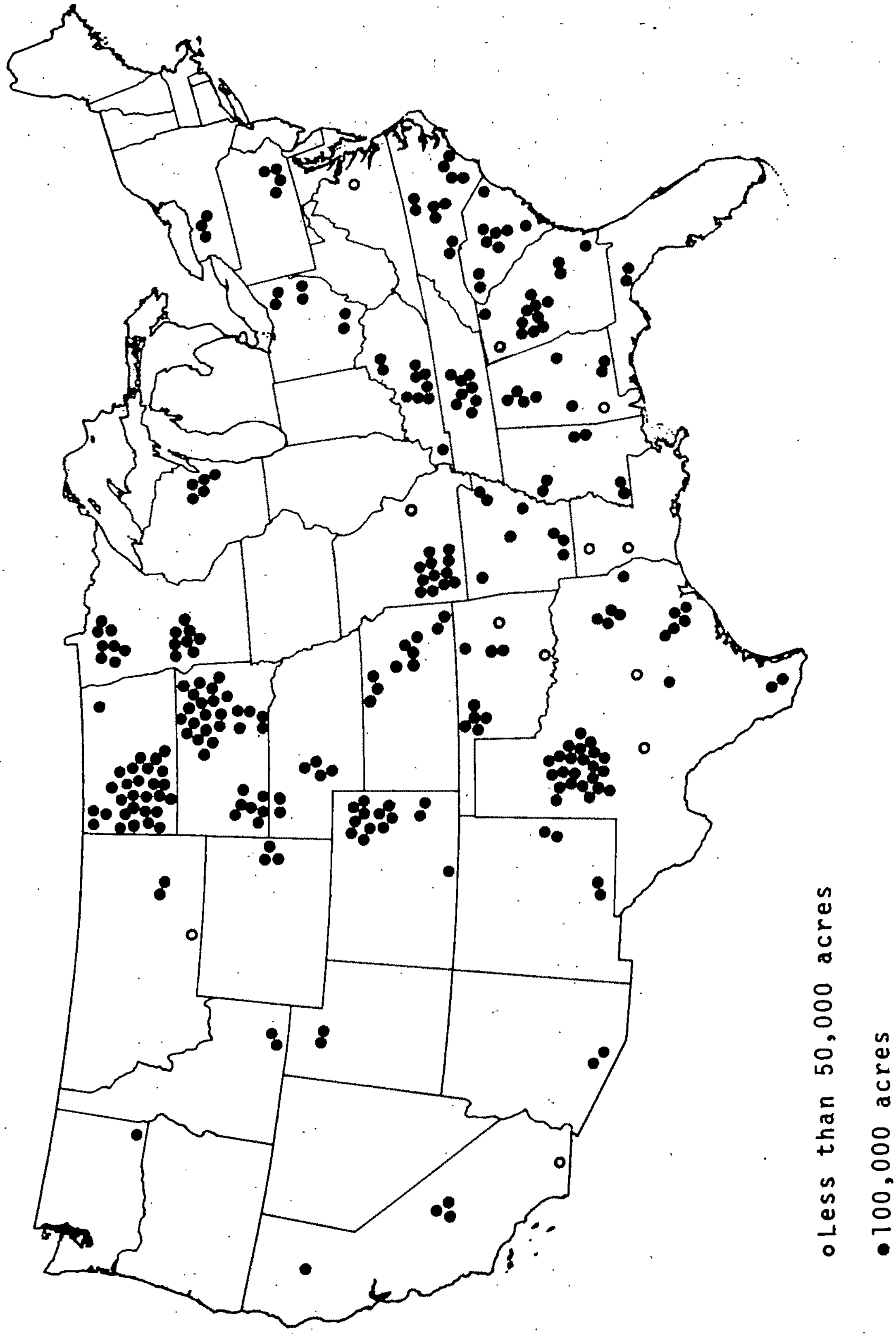

Figure 2. The location of cropland not used for crops in option 1

costs 10%, option 3, results in a shift in land utilization similar to that of option 4, but the extent of the shift is smaller; unused cropland in North Dakota increases 683,187 acres. In option 9, 753,016 more crop acres in western Minnesota are used and 424,780 acres in Ohio, Kansas, and Texas go unused compared to option 1. At national average yields, this shift represents less than 8% of the land needed to produce the additional demand at Seattle.

Total crop production costs did not differ significantly among the first nine options. These results suggest that moderate changes in transportation costs similar to those of options 2 through 7 would not have significant impacts on national yields, land use, or production costs. Currently, a major transportation policy issue concerns the financial condition of railroads. Our results suggest that 10% or 20% rail rate increases would have minimal effects on yields, land use, and nonland production costs. Such a change would not significantly shift the location of grain production from, for example, the Corn Belt to the Southeast. Similarly, if user charges equivalent to 10% to 20% of barging costs were imposed on barge traffic, there would be no significant shifts in location of grain production from the Corn Belt to the Delta States, even though substantial quantities of grain are now barged from the Corn Belt to Gulf ports.

Shifts in the location of demand, such as from the Gulf ports to Seattle in options 8 and 9 also result in very small changes in yields, land use, and production costs. This shift is only one of several possible shifts in the distribution of exports among port regions; however, it is probably one of the more likely and one that would result in more dramatic effects. Also, it is likely to occur to some degree because (*a*) ports in the Northwest have deep water, (*b*) more exports may go to Asian countries because of their growing population and opening of trade, (*c*) the Panama Canal cannot accommodate the very large ships, (*d*) multicar rail shipments can be used to deliver grain to ports in the Northwest, and (*e*) the Gulf ports are congested. Other possible shifts in the distribution of export demands could arise from the inability of large ships to sail the St. Lawrence Seaway, the development of deepwater ports off the Atlantic coast, and further expansion of the Gulf ports such as at Mobile.

Prices

Shadow prices computed prior to transportation in the model are called "county elevator prices" because they represent supply prices at producing regions. Shadow prices after transportation are called "consuming region prices" because they represent supply prices at points of processing, feeding, or export (table 5).[13] Prices for any one option depend on the nonland production costs, demands, yields, land constraints, crop activity bounds, transportation costs, and the structure of the model. Consequently, the important analysis is the variation in prices among the options. Then, for example, even if the demand projec-

[13] If intraregional transportation costs were included, the price changes, especially at the consuming regions, would be somewhat greater.

Table 5. Estimated National Average Grain Prices at Country Elevators and at Consuming Regions

	Feed Grains[a]		Soybeans		Wheat	
Option	Country Elevator	Consuming Region	Country Elevator	Consuming Region	Country Elevator	Consuming Region
			($ per Bushel)			
1. Single car	1.336	1.431	2.563	2.641	1.786	1.946
2. 50-car	1.337	1.426	2.565	2.640	1.793	1.940
3. 10% rail	1.340	1.441	2.579	2.660	1.792	1.962
4. 20% rail	1.345	1.452	2.598	2.682	1.800	1.982
5. 10% barge	1.338	1.434	2.564	2.644	1.789	1.948
6. 20% barge	1.341	1.438	2.569	2.650	1.794	1.953
7. Alternative single-car	1.336	1.431	2.562	2.642	1.789	1.950
8. 10% Gulf-Seattle	1.338	1.434	2.564	2.645	1.810	1.969
9. 25% Gulf-Seattle	1.326	1.424	2.551	2.640	1.814	1.974
10. 25% exports	1.949	2.039	4.298	4.391	2.803	2.969

[a] Corn equivalent units.

tions for 1980 prove to be incorrect, analyses of results from the model will still be relevant.

Most of the effects of the differences among options 1 through 9 are absorbed by price changes and returns to resources rather than the relocation of grain production. Consequently, policymakers should expect changes in relative rates among transportation modes to be reflected largely in price changes, while the stability of the location of grain production is maintained. This conclusion is reached by comparing the variation in country elevator prices and production costs among the options and recalling the stability of the location of production discussed earlier. The percentage differences between the high and low country elevator prices among options 1 through 9 for feed grains, soybeans, and wheat are twelve to fifteen times greater than the percentage differences between the high and low nonland production costs. Thus the results suggest that transportation costs and export demand shifts among ports have a much larger impact on prices than on yields, location, and nonland production costs.

For feed grains, soybeans, and wheat, national average country elevator prices increase and the average consuming region prices decline when multicar, option 2, versus single-car, option 1, rail shipments are used (table 5). This suggests that multicar systems similar to the one in option 2 have the potential of increasing farm prices and lowering consumer food costs. In option 2, fifty-car rail units are used for all rail shipments except those that are a part of multimodal shipments. Some of the shipments hauled solely by rail in option 2 are in reality too small to support a fifty-car unit system. Thus, it is unlikely that a multicar system similar to the one in option 2 will be universally developed. The development of a multicar system would tend to increase grain prices and returns to resources in those regions that could effectively adopt it, i.e., those regions with intense production and a large volume of outbound shipments. It would have the opposite effect in regions of sparse production and small exports. Consequently, the development of an effective multicar system will not be beneficial to all localities, even though it may be nationally beneficial. The regions that adopt an effective multicar system will require a reorganization of the assembly of grain for rail shipment, which has income and employment implications for many rural towns. There has been a tendency for railroads to only utilize multicar shipments to compete with barges. But multicar shipments should be considered for other routes, such as shipments from the Corn Belt to the Northwest, because they may reduce total transportation costs and thereby improve farm and consumer prices.

Greater rail and barge costs in options 3 through 6 increase prices at both country elevators and consuming regions compared to option 1 (table 5). The consuming region prices increase more than country elevator prices except for wheat with higher barge costs, options 5 and 6. This suggests, given fixed quantities demanded, the consuming region prices tend to absorb the majority of the price changes that result from rail and barge cost increases. If the assumption of fixed quantities demanded were relaxed, the impacts would result in both price and quantity changes. The more elastic the demands, the greater the effects on the quantities demanded. Price changes for the alternate single-car option, compared to option 1, depend on the average distance grain is hauled. Country elevator and consuming region feed-grain prices are unchanged because on the average they are hauled medium to long distances. But the country elevator-consuming region price spread increases for soybeans and wheat because their average haul is relatively short. The 10% shift in export demands from the Gulf to Seattle compared to option 1 results in higher country elevator and consuming region prices for feed grains and soybeans, but these prices are lower for a 25% shift, option 9. Country elevator and consuming region wheat prices are higher in options 8 and 9 than in option 1 because a large volume of wheat is grown near and exported from the Northwest. The differences in prices among the first nine options seem small, but they are not meager in terms of total national impact. Total feed-grain, soybean, and wheat production with the base level of exports is projected to be 11.2 billion combined bushels in 1980. A 1¢ per bushel change would thus have a national value of $112 million.

Conclusions

The results of the analysis provide implications for certain national policies. The analysis utilizes costs of providing transportation rather than transportation rates, but neverthe-

less the results can be applied to similar actual rate changes.[14] Among innovations and policy changes that could have effects similar to those that result from the options of the model are adoption of a multicar rail system on a broad scale, higher rail rates to strengthen the financial position of railroads, and the implementation of fees for recouping the capital investments in the inland waterways.

Specific variations in transportation costs produce substantial changes in the quantities and directions of individual interregional grain flows, but only small changes in the location of production and in the total of all interregional flows. Transportation cost changes have a much larger impact on prices and returns to resources than on the location of production. The effects on prices and returns to resources are not uniform among the regions; both their magnitudes and directions vary. Hence, analyses of specific transportation policies should concentrate on regional income and price effects rather than on the location of production.

Attention has focused on shifting exports from the Gulf ports to ports on the Northwest coast. If this shift occurs, there is likely to be a substantial change in the pattern of grain flows and some changes in the production location of particular crops, but cropland that is idle before the shift will likely remain idle. The greater the increases in exports and the shifting of the demand for exports to the Northwest, the greater the need for additional rail capacity. The quantity of grain carried on the inland waterways will stabilize near present levels, unless there is a substantial change in export levels or the ports from which it is exported.

The analysis of fuel costs is not specifically incorporated into the model, however, some imperfect comparisons between higher fuel costs and the model options can be made. For example, the doubling of fuel costs in 1973 through 1974 is similar to option 5 because introducing such a fuel price change into the model increases barge and truck costs about 10% more than rail costs increase (Fedeler, Heady, and Koo, pp. 182–85). A change in the choice of transportation mode is likely to be one of the major effects of higher fuel costs with regard to grain traffic. Railroads are likely to increase their share of the traffic because higher fuel prices induce greater percentage increases in total costs for both barges and trucks than for railroads (Fedeler, Heady, and Koo, pp. 179–82).[15]

Relationships between the grain and transportation industries need further exploration. Both industries contain large, long-term investments. The research summarized demonstrates their interdependence. Investments appropriate in one industry could readily become unprofitable with changes in the other. The dynamics of world trade, grain prices, fuel supplies and costs, etc., suggest the interdependence of the two industries is especially important at this time.

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[14] Although most transportation rate changes have been local, others have been nearly uniform across the nation and similar to those specified among the options. For example, nearly all railroads utilized a 7% freight rate rise in April 1975 and most were in agreement in requesting additional industry-wide increases of 5% and 2.5% that would take effect later.

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Modeling the Optimal Location of the Cattle Feeding Industry

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A variety of interregional linear programming models have been used to study the optimal location of the cattle feeding industry. An analysis is performed to determine which factors are most influential in determining feedlot location and thus need to be included in these models. In addition to traditional factors, consideration is given to the effects of region definition and regional land use patterns. Results indicate the importance of feeders, grain, and land use patterns. The implications of these results in the analysis of future trends in feedlot location is discussed.

Key words: cattle feeding, land use, linear programming, location, region selection.

In the past fifteen years, many agricultural economists including Bhagia, Dietrich, Goodwin, and King have set about the task of modeling the optimal location of the cattle feeding industry. Each model has some unique considerations and some considerations that are common to all. The purpose of this paper is to evaluate these considerations to see which ones are most important in determining the optimal location of the cattle feeding industry. In addition, two new considerations are proposed and evaluated.

First, we attempt to evaluate the effect of selection of cattle feeding regions and resource regions on the optimal location of the industry. Different sets of regions are defined for each spatial variable. In addition, the number of regions for each spatial variable is much greater than the number of cattle feeding regions. Second, we postulate that feedlot locations may be affected by regional differences in land use patterns. For example, in the densely populated Northeast, expansion of the feedlot industry would be less likely to occur than in the sparsely populated Southwest.

A linear programming model that minimizes the regional nonfeed costs and the transportation costs of resources and finished product is used. In addition to the new model considerations defined above, the model includes the traditional considerations of feeder cattle, grain and roughage availability, grain and roughage demanded by other animals, and slaughter capacity. Data were developed for the year 1972 from standard U.S. Department of Agriculture publications (1972, 1973a, b). The specific values used in the model, as well as the sources and method of calculation, are shown in Byrkett (1974).

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Region Selection

The United States was divided into sixteen cattle feeding regions as illustrated in figure 1. These regions were formed by grouping states around areas of high fed beef production, but individual states were not subdivided in order to facilitate the accumulation of regional data.

Previous studies used the same regions defined for cattle feeding to describe the distribution of each spatial variable. This has two possible disadvantages. First, the regions may not conform to a logical spatial distribution of the given resource. Second, there may be insufficient regions for accurate results. For this study, different regions are defined for each resource. These regions are much larger in number than the number of cattle feeding regions and are designed to describe a logical distribution of each resource. However, as in defining cattle feeding regions, individual states are not subdivided. There are thirty feeder cattle regions, twenty-nine grain regions, thirty-two roughage regions, thirty

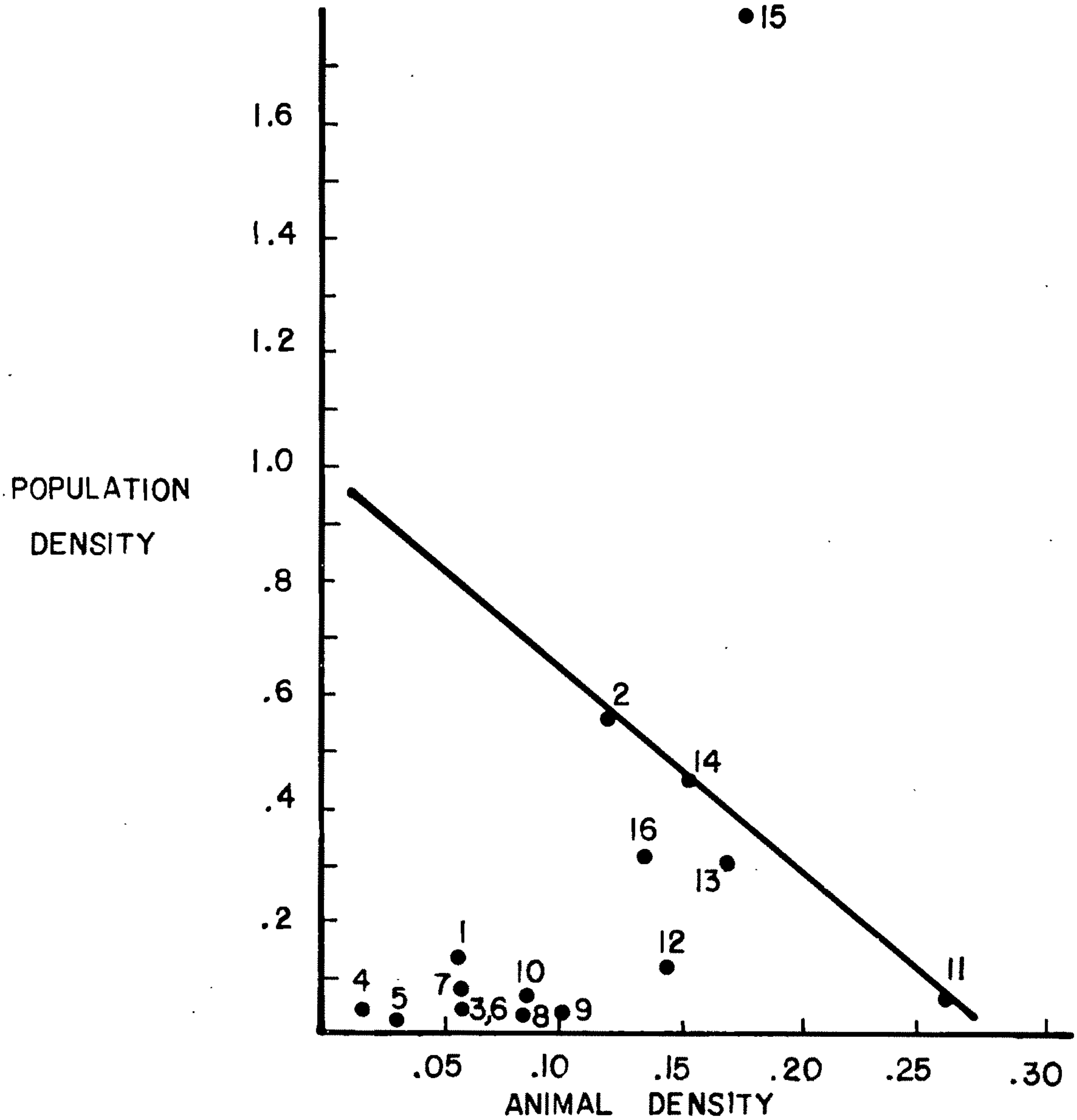

Figure 1. Sixteen cattle feeding regions

slaughter regions, and thirty-two beef demand regions. The assignment of states to regions is contained in table 1.

Regional Land Use Patterns

A new consideration is proposed to limit the expansion of the cattle feeding industry in regions of high competition among alternate uses of the land. This consideration is important for two reasons. First, if the cost of land is extremely high due to the competition for alternate uses, it may be uneconomical to use the land for beef production. Second, in areas of high population density, the conflict between animals and people may limit production. This conflict may arise over such things as odor, noise, or the disposal of wastes.

To model the effect of regional land use patterns on the location of the cattle feeding industry, the regional nonfeed costs per head are permitted to vary according to the production level in a given region. In regions where the competition among alternative uses of land is extremely high, this cost curve rises very rapidly at production levels above the current production level and almost imposes

Table 1. Assignment of States to Regions

State	Feeder Cattle Region	Grain Region*	Roughage Region*	Slaughter Region	Beef Demand Region
Alabama	25	(6)	(4)	29	24
Arizona	6	3	9	6	6
Arkansas	15	(4)	(2)	18	17
California	3	(2)	3	3	3
Colorado	9	5	10	8	7
Connecticut	27	(7)	24	25	26
Delaware	27	(7)	25	26	29
Florida	30	(10)	(6)	30	32
Georgia	25	(6)	(4)	29	31
Idaho	4	2	4	4	5
Illinois	21	16	19	19	19
Indiana	23	18	21	21	21
Iowa	18	13	16	16	15
Kansas	14	11	14	12	11
Kentucky	24	(5)	22	22	22
Louisiana	16	(4)	(3)	18	18
Maine	27	(7)	24	25	26
Maryland	27	(7)	25	26	29
Massachusetts	27	(7)	24	25	26
Michigan	22	17	20	20	20
Minnesota	17	12	15	15	14
Mississippi	25	(6)	(4)	18	18
Missouri	19	14	17	17	16
Montana	7	4	6	7	4
Nebraska	13	9	13	11	10
Nevada	5	(3)	5	3	3
New Hampshire	27	(7)	24	25	26
New Jersey	27	(7)	25	26	27
New Mexico	10	6	(1)	9	8
New York	27	(7)	24	25	27
North Carolina	29	(9)	(5)	28	30
North Dakota	11	7	11	10	9
Ohio	26	19	23	24	25
Oklahoma	15	11	(2)	13	12
Oregon	2	(1)	2	2	2
Pennsylvania	27	(7)	25	26	28
Rhode Island	27	(7)	24	25	26
South Carolina	29	(9)	(5)	28	30
South Dakota	12	8	12	10	9
Tennessee	24	(5)	22	23	23
Texas	16	6	(3)	14	13
Utah	5	(3)	8	5	5
Vermont	27	(7)	24	25	26
Virginia	28	(8)	26	27	29
Washington	1	1	1	1	1
West Virginia	28	(8)	26	27	29
Wisconsin	20	15	18	19	19
Wyoming	8	4	7	7	5

* Numbers in parenthesis indicate grain or roughage deficient regions.

a constraint. In regions where this competition is low, the cost curve rises very slowly, imposing almost no constraint.

The development of these nonlinear nonfeed cost curves is based on the assumption that areas of high population and animal density tend to have greater competition for land resources and greater conflict between animals and people. Thus, the nonfeed cost curves would rise very rapidly at production levels above the current production. Conversely, nonfeed costs for regions with low population and animal densities would increase less rapidly. This conflict between human and animal population suggests a point at which the two may no longer coexist without nonfeed costs becoming prohibitively high. The approach used to model these increasing nonfeed cost curves was to estimate the increase in production possible in each

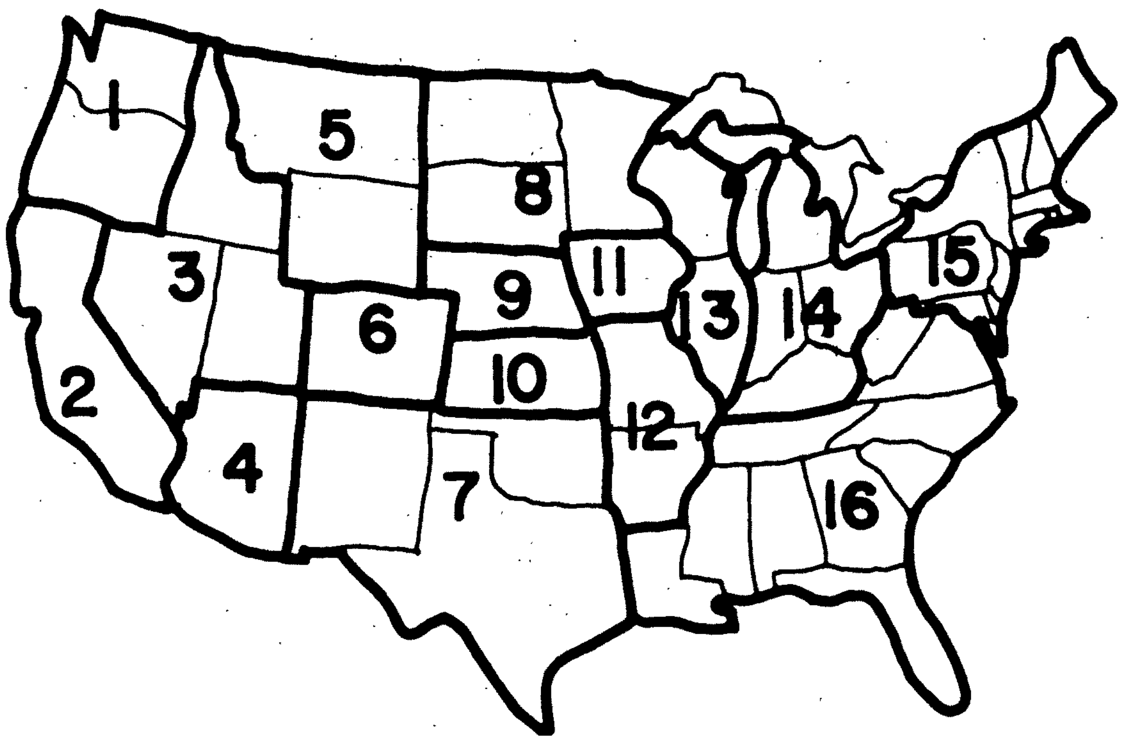

Figure 2. Scatter plot of population density (people/acre of farmland) versus animal density (grain and roughage consuming animal units/acre of farmland) for each cattle feeding region

region before nonfeed costs would become prohibitive. These estimates were obtained by plotting animal density per acre of farmland (USDA 1972, 1973a) versus population density per acre of farmland (USDC 1973, USDA 1973a) for each region as illustrated in figure 2. The line drawn through regions 2, 11, and 14 represents the assumed maximum combinations of human and animal population density possible for the production of feedlot cattle. In these three regions, as well as region 15, cattle production has been declining in recent years (USDA 1973b), concurrent with increasing population/urbanization. Thus, it is assumed that these regions are at or near the maximum level of cattle production possible. Furthermore, it is assumed that region 15 is beyond an acceptable level and that cattle production in this region will continue to decline.[1]

Using this figure, the increase in animal density possible at the current population density was calculated for each region. For example, region 1 has a population density of 0.15 people per farm acre and an animal density of 0.06 grain and roughage consuming animal units per farm acre. At the population density of 0.15, the animal density could increase to 0.24 before hitting the maximum production line. Thus, it is estimated that the maximum production level possible for region 1 is four times the current production level. Similar estimates were made for all regions as follows: region 1—4.0, region 2—1.0, region 3—4.5, region 4—13.4, region 5—9.3, region 6—4.5, region 7—4.4, region 8—3.4, region 9—2.8, region 10—3.4, region 11—1.0, region 12—1.8, region 13—1.1, region 14—1.0, region 15—1.0, and region 16—1.5. Admittedly, little confidence can be placed in the estimated maximum production level but, as indicated in the footnote, we feel that the relative differences between regions are reasonable.

Using this estimate of maximum production level, the following equation was used to represent the inverse relationship between nonfeed costs and production capacity remaining in a given region: $NFC = (MP-CP)\ C/(MP-PL)$, $PL > CP$, where NFC = nonfeed cost (dependent variable), PL = production level (independent variable), C = estimated nonfeed cost at current production level in

[1] To test the sensitivity of this limit, an alternate population limit was evaluated. This case permitted 50% more production before the maximum was obtained but produced little change in the results (Byrkett 1974). It was thus concluded that the important consideration was the relative difference between regions, rather than the absolute increase in production possible.

Table 2. Comparison of Optimal and Actual Production Levels, 1972 (in thousands of head)

Cattle Feeding Region	1972 Actual Production Level	1972 Optimal Production Level	Percentage Deviation from Actual
1	518	718	39
2	2,062	872	−58
3	637	399	−37
4	899	569	−37
5	321	54	−83
6	2,291	2,605	14
7	5,310	5,939	12
8	1,581	1,414	−11
9	3,990	4,590	15
10	2,405	3,305	37
11	3,986	3,986	0
12	638	638	0
13	1,217	1,217	0
14	1,256	1,256	0
15	194	194	0
16	628	319	−49

given region, CP = current production level in given region, and MP = maximum production level in given region. The nonlinear nonfeed cost curve resulting from this equation was then approximated by a series of six steps. Each step requires an additional constraint; that is, at step 1, one can produce up to a certain production level at a given cost per head and, at step 2, one can produce up to a higher production level at an increased cost per head and so on.

Base Case

Table 2 contains a comparison of the actual production levels in 1972 and the optimal production levels calculated by the model. By comparing these production levels, one may postulate the areas of growth and decline. Regions 11 through 15 show no deviation from the optimal because it is advantageous to produce as much beef as possible in these regions, but they are limited by the land use constraint to their current production level. In spite of some of the large deviations from actual, the results seem fairly reasonable, since most of these large deviations occur in regions of very small production. The most disturbing result is the large deviation in the optimal production of region 2 (California) from the actual. Recent years have shown a decline in California feeding but not to this extent. However, a sensitivity analysis of the California nonfeed cost lends further support to this decline. The results do support the general conclusions of Dietrich and Goodwin concerning the growth of cattle feeding in the central and southern plains.

Sensitivity of Costs in Base Case

The particular question addressed in this section is the sensitivity of the base case to the estimates of regional nonfeed costs and transportation costs. The approach used was to vary each cost parameter up or down until the solution changed. This procedure was followed for all variables in the basis and the average percentage increase and decrease was calculated for each type of cost. These averages and the upper and lower figure in each average are listed in table 3. This table demonstrates the robustness of the linear programming model, particularly with respect to the

Table 3. Average Percentage Deviation of Basis Variable Cost Parameters without Changing Solution

	Upper Limit			Lower Limit		
Type of Cost	Average Deviation (%)	Maximum Deviation (%)	Minimum Deviation (%)	Average Deviation (%)	Maximum Deviation (%)	Minimum Deviation (%)
Nonfeed	6	23	0	2	8	0
Feeder transportation	58	359	0	19	96	0
Grain transportation	13	92	0	14	100	0
Roughage transportation	42	238	0	53	100	0
Slaughter cattle transportation	30	246	1	9	35	0
Carcass beef transportation	135	896	0	24	95	0

Table 4. The Effect of a 10% Change in Nonfeed Cost on the Optimal Production Levels (In thousands of head)

Cattle Feeding Region	Base Case	Optimal Production with a 10% Decrease in Nonfeed Cost	Optimal Production with a 10% Increase in Nonfeed Cost
1	718	734	618
2	872	1,172	872
3	399	499	114
4	569	899	393
5	54	221	54
6	2,605	2,706	2,521
7	5,939	6,867	5,137
8	1,414	1,781	788
9	4,590	4,890	4,282
10	3,305	3,605	2,804
11	3,986	3,986	3,937
12	638	688	44
13	1,217	1,217	591
14	1,256	1,256	706
15	194	194	194
16	319	628	87

transportation costs. The results indicate that some of the transportation cost figures could be in error by as much as 50% without changing the solution.

On the other hand, the nonfeed cost ranges indicate that even a fairly small error in the estimation of these costs may alter the optimal solution. One could expect that these alterations would have a very direct effect on the optimal location of the cattle feeding industry. With this problem in mind, a further sensitivity analysis was performed on the nonfeed cost parameters. Each nonfeed cost was varied individually by plus or minus 10% to observe the effect on the optimal location of the cattle feeding industry. Table 4 contains the resulting production levels caused by the change in nonfeed cost for each region. This may be compared with the results of the base case to obtain an idea of the range of the resulting optimal solution. The results indicate that a change in nonfeed costs for regions 1, 6, 7, 9, 10, 11, and 15 have little effect on the equilibrium production levels. For region 2, the production should not go below the optimal but may be higher if the nonfeed costs were overestimated. However, this does not change the general conclusion of reduced cattle feeding in California. Regions 3, 4, 5, and 16, although involving large percentage changes, involve very small changes in absolute numbers. For regions 8, 12, 13, and 14, the production should not go above the optimal but may be lower if the nonfeed costs were underestimated.

The main conclusion from this analysis is that nonfeed costs are the most sensitive costs in determining feedlot location, but the possible errors in nonfeed cost estimation are not sufficient to alter the general conclusions obtained.

Analysis of Model Structure

Recall that the objective of this paper is to determine which considerations or factors have a significant impact on the location of the cattle feeding industry. The method of studying these questions is to compare the results obtained without the given consideration in the model to the results in the base case. The assumption is that the base case contains the most accurate results, since it includes all of the considerations. Table 5 contains the results obtained by individually removing feeder cattle constraints, grain constraints, roughage constraints, slaughter capacity constraints, and regional land use pattern constraints, respectively, from the model. In addition, table 5 contains the results obtained by using the same sixteen cattle feeding regions for all spatial variables. The conclusion obtained by removing each type of consideration is discussed in the paragraphs that follow.

Feeder Cattle Availability

The importance of the availability of feeders to regions 2 (California), 3 (Idaho, Utah and Nevada), and 16 (Southeast) is dramatically illustrated as the optimal production in these regions is reduced greatly when feeder cattle availability is no longer considered in the model. Basically, the remainder of the United States is hardly affected except regions 4 (Arizona) and 7 (Southern Plains) pick up the production lost by the other regions.

Grain Availability

Like feeder cattle, it is very clear that grain is an important factor affecting feedlot location as evidenced by the significantly large deviations from the base case. The shortage of grain in regions 2 (California), 4 (Arizona), and 16 (Southeast) is clearly illustrated by the large increases in production that would be optimal

Table 5. Optimal Production Levels without Considering Certain Constraints in the Model (in thousands of head)

		Constraints Not in the Model					
Cattle Feeding Region	Base Case	Feeder Cattle	Grain	Roughage	Slaughter Capacity	Additional Resource Regions	Land Use Patterns
1	718	734	618	718	718	734	734
2	872	0	2,062	872	964	1,601	872
3	399	0	432	399	376	306	250
4	569	1,299	1,226	569	676	279	676
5	54	54	54	54	93	54	54
6	2,605	2,744	2,691	2,605	2,691	2,306	2,544
7	5,939	6,511	5,657	5,958	6,149	5,393	4,378
8	1,414	1,524	927	1,288	929	1,781	506
9	4,590	4,685	3,990	4,590	4,290	4,514	4,685
10	3,305	3,305	2,705	3,305	3,305	3,005	5,813
11	3,986	3,986	3,986	3,986	3,986	3,986	4,722
12	638	611	638	638	638	688	0
13	1,217	1,217	1,217	1,217	1,217	1,267	591
14	1,256	1,207	1,256	1,256	1,256	1,256	945
15	194	194	194	194	194	194	908
16	319	87	510	445	678	678	87

were it not for the grain constraints. Conversely, the central area of the United States, regions 7, 8, 9, and 10, would lose some production, if it were not for their advantageous grain position. Though these results are not reported in this paper, it was found that it is not necessary to simultaneously optimize the shipments of grain to cattle feeding regions and grain deficient regions (Byrkett 1974).

Roughage Availability

These deviations are all well within the sensitivity limits of the data established in table 4, and, thus, one must conclude that it was not necessary to model roughage as a factor affecting the optimal location of cattle feeding. This supports the conclusions of Dietrich and Goodwin, who did not include roughage considerations in their models.

Slaughter Availability

The almost negligible effect of slaughter capacity on these results is quite surprising. The only significant deviations are in regions 5 (Montana and Wyoming) and 16 (Southeast). This result is somewhat surprising because this factor has received more discussion in the literature than any of the other factors (Goodwin and Langemeier). This discussion is based on the mobility of slaughter facilities. The other factors are fairly well fixed in their location due to climate and soil conditions, but slaughter facilities may be placed anywhere. This removes slaughter availability from consideration as a fixed constraint.

Spatial Detail

To determine if this extra detail in defining resource regions is really necessary, a model was devised using the same sixteen cattle feeding regions for all of the resources and using the same centers of cattle feeding as the central point for all regions. All of the resource availabilities and beef demand were aggregated to the sixteen cattle feeding regions. All other data remained exactly the same except transportation costs, which were based on mileages between cattle feeding centers.

Table 5 contains the optimal location of cattle feeding as determined from the sixteen region model, that is, without the additional resource regions. These results indicate large differences in five out of sixteen cattle feeding regions, regions 2, 4, 6, 13, and 16. The most significant difference is in region 2 (California), where the optimal production level changed from 872,000 head to 1.601 million head. These results quite vividly indicate the importance of greater spatial detail in defining the resource regions. Using the same sixteen cattle feeding regions for all resources did not provide great enough detail to obtain the accuracy desired.

Regional Land Use Patterns

This factor has a tremendous impact on the regional location of cattle feeding as illustrated by the significant differences in regions 7, 8, 10, 11, 12, and 15. One might also add that the results obtained using this factor agree much more closely with 1972 data, which increases confidence in the validity of the model. For example, the optimal production in region 15, without considering the regional land use patterns, is nearly five times the current production. Clearly, it is unrealistic to expect this kind of growth in the Northeast. Naturally, when the Northeast is limited to the more realistic current production, other eastern regions, regions 8, 12, 13, 14, and 16, are brought up to more realistic levels.

Summary and Implications

A cost-minimization linear programming model was developed to model the optimal location of the cattle feeding. The following results were obtained. (*a*) Feeder availability and grain availability strongly influence the location of cattle feeding. (*b*) Roughage availability is not a primary concern in the location of cattle feedlots. (*c*) Slaughter capacity will influence the location of cattle feeding in the short run, but in the long run slaughter facilities will move to the feedlots. (*d*) In modeling the location of cattle feeding, it is important to use a greater number of resource regions than cattle feeding regions. (*e*) Land use patterns that reflect both the competition for land resources and the conflict resulting from efforts to eliminate problems associated with odors, solid waste disposal, and water pollution in areas of high population density is an important factor influencing the location of cattle feeding.

These results have strong implications in several areas affecting the cattle feeding industry. Recent trends (Nicol and Heady) show that the proportion of feeder cattle production is increasing in the Central Plains and the Southeast and that the proportion of grain production is increasing in the Lake States, Corn Belt, Southern Plains, and the Southeast. Due to the importance of these factors of production, one may expect cattle production to continue to decline in coastal areas and to increase inland.

The effect of increasing fuel or transportation costs is somewhat uncertain. (Byrkett 1974). Fuel costs for transporting feeders and grain may be minimized by feedlot location in the inland states, while fuel costs for transporting the beef to market may be minimized by feedlot locations near the coastal population centers. These opposing forces in conjunction with the insensitive nature of the transportation costs tend to counterbalance each other in determining feedlot location.

Changes in cattle feeding technology may effect the location of cattle feeding in three ways. First, as commercial feedlots become more dominant, nonfeed costs will become more competitive in some regions. For example, Corn Belt nonfeed costs are much higher than those in the Southern Plains due partly to the greater proportion of farmer feeders. Thus, increasing commercialization will lower certain nonfeed costs and, due to the sensitive nature of these nonfeed costs, trends in cattle feeding production may change.

Second, changes in cattle feeding technology may allow cattle and people to live in harmony and thus reduce the important land use conflict consideration. For example, the feedlot of the future may be a multistory building that is completely enclosed and odor free with a total waste recycling and/or composting operation. This type of facility may be no more obnoxious than a typical midwestern manufacturing plant and thus fits in better with the structure of society in the population centers.

Third, new environmental requirements may effect nonfeed costs differently throughout the country. Byrkett (1975) found that the Federal Water Pollution Control Act Ammendments of 1972 will have little effect on the location of cattle feeding but given the sensitivity of these nonfeed costs, later changes in the legislation may alter this conclusion. Incidentally, these results are in agreement with those published by Forster indicating the small effect of this legislation on Michigan cattle feedlot performance.

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Framework for Economic Analysis of Grain versus Harvested Roughage for Feedlot Cattle

Ray F. Brokken, T. M. Hammonds, D. A. Dinius, and John Valpey

Traditional models for assessing technical and economic efficiency of cattle feeding were found inadequate. An alternative framework is developed for estimating effects of changes in ration nutrient concentration on animal performance under a range of production conditions and types of animals. The framework is incorporated in a dynamic profit function and its use discussed and demonstrated under various optimizing criteria. High energy rations remained economical even at relatively high grain prices. This framework implies sigmoid shaped grain-roughage isoquants; concave to the origin over the finishing range of grain-roughage ratios, and convex at lower grain-roughage ratios.

Key words: beef, cattle, efficiency, feed energy, feedlot, optimum rations, rations.

Cattle are versatile animals and can be grown on diets varying widely in the proportions of grain and roughage. Over most of the past several decades, the cost of growth in cattle has been lower in the feedlot than on pasture or range, and the cost per calorie of net energy has been lower from grains than from roughages. Now, because of generally higher feed prices and changes in the price of grains relative to roughages, questions are raised about traditional rations and even whether cattle should be grown in feedlots at all. Answers to these questions involve physical and economic efficiency considerations, consumer preferences, and ethical and political considerations as well. Certainly, political and ethical considerations should be based on knowledge of physical and economic efficiencies and the trade-offs involved and not on misinformation about them.

The authors have observed much misunderstanding about the basic relationships and trade-offs by those concerned with these issues, including not just the popular press and lay public, but agricultural economists and animal scientists as well. Such misunderstanding can lead to perverse recommendations and policy. Contributing to this misunderstanding is the fact that traditional analytical frameworks are inadequate.

The primary purposes of this paper are to present a technical framework for estimating the voluntary feed consumption and performance of different types of cattle for diets ranging widely in nutrient and energy concentration, to describe the technical information needed to bring the framework to its full potential in economic analysis, and to illustrate use of the technical framework in economic analysis.

First, some traditional analytical approaches and their limitations are discussed. Second, the general framework for describing voluntary feed intake and research needed to bring it into a more complete operational level is presented. Then, voluntary intake and energy requirements functions are specified for three animals that allow estimation of total feed requirements and growth from diets ranging widely in roughage and grain content. Finally, a dynamic profit function and an economic analysis of grain-roughage substitution is presented. The primary focus of the

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paper is on the technical research needs and its primary contribution is as a guide to some further multidisciplinary animal research.

The results of the economic analysis are interesting, because they suggest that a high concentrate diet remains economical even at quite high grain prices. However, the main contribution of the economic analysis is in illustrating the workings of the technical framework and theory in the economic model and in illustrating the potential economic importance of further technical research.

Traditional Approaches

The production function with isoquants, expansion lines, and ridge lines provides a traditional model for economists. A casual mental construction of technical substitution between roughage and grain in the finishing phase of beef production may suggest an optimum balance that is very sensitive to small shifts in ratios of ingredient prices. However, this has not been the case.

Feedlot rations in recent years have typically contained only what is regarded as a physiological minimum of roughage. Not only has grain been much cheaper per unit of net energy but less net energy is required to produce a given gain from the higher concentrate rations. The reason for the latter point is that higher roughage rations require more days of animal maintenance to produce a given amount of growth than do high concentrate rations. Hence, the optimum combination of grain and roughage has been firmly located at the ridge line defining a physiological (or a safe) minimum level of roughage.

The grain to roughage price ratios of a few years ago were such that a very large increase in the ratios was necessary to move economically away from the minimum roughage ridge line. Movement along the isoquant away from this point entails more time, yardage, feed preparation, and interest, items that are easily overlooked in casual analysis with this framework.

It is very difficult to explicitly incorporate rate of gain, time, difference between animals, specific beginning and ending weights, and other complicating variables into the traditional production function framework. For this reason, the framework has never proved practical in commercial application and has only limited usefulness in theoretical considerations.

The California net energy system (Lofgreen and Garrett, National Academy of Sciences) has provided a very useful estimate of energy requirements for maintenance and growth for many, but not all, animals. This system also provides an improved basis for assessing relative feed values of various ingredients for use in ration formulations with linear programming (Brokken 1971a, c; Scott and Broadbent). A major difficulty in applying this system over diets ranging widely in energy content is the lack of information about how voluntary feed (energy) intake is affected by changing the energy concentration (calories per pound) of the diet.

Montgomery and Baumgardt (1965a) have proposed a general relationship to describe feed intake regulation in relation to dietary energy concentration. At low levels of ration energy concentration (calories per pound of ration), intake is limited by stomach capacity, but as a certain level of energy concentration is reached, the rumen fill ceases to limit intake and further increases in ration energy concentration result in a decrease in feed intake (see figure 1). While dry matter (DM) intake is declining at the higher energy intake, the higher energy concentration permits approximate maintenance of digestible energy intake. This has led to the conclusion that with diets such that rumen fill is not limiting intake the animal consumes for its needs in terms of its inherent genetic capability for growth. How-

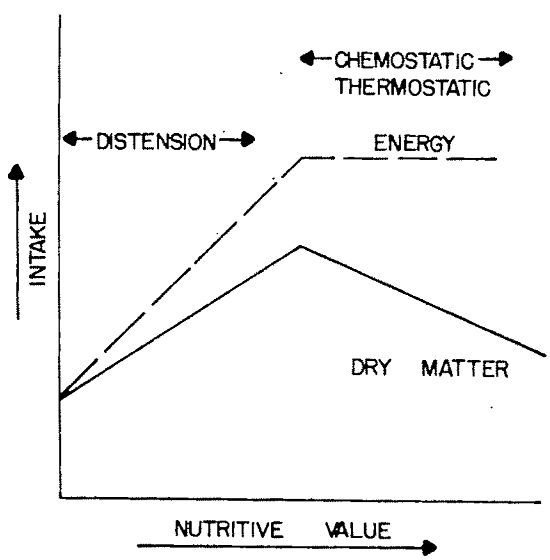


Figure 1. Proposed relations in regulation of feed intake in ruminants (Montgomery and Baumgardt)

ever, it is known that net energy (NE) as a proportion of digestible energy (DE) increases as the DE concentration increases. Then, if DE intake were to remain constant as ration energy concentration increases, NE intake must be increasing. This implies an increasing rate of gain as ration energy concentration increases, which is indeed the case. Further, if daily dry matter intake, Y, is a linear function of energy concentration, X; i.e., if $Y = f(X)$, then energy intake, $XY = X\,f(X)$, is nonlinear and vice versa. Figure 1 is inconsistent in this respect. However, the empirical work of Montgomery and Baumgardt (1965a), Dinius and Baumgardt, and Dinius et al. corroborates the dry matter intake relationship. These relationships have been reexamined and are reported in detail elsewhere (Brokken and Dinius 1974, 1976; Dinius et al.). Their work provides a framework which accommodates differences between individual animals for estimating the effect on voluntary daily feed intake and daily gain of changing dietary energy concentration. In figure 1 voluntary daily dry matter intake is increasing to a peak then decreasing as energy concentration increases. To the right of the peak it is hypothesized that chemostatic and/or thermostatic mechanisms regulate intake. To the left of the peak, gut fill limits intake. However, the daily intake declines leftward with decreasing energy concentration because the rate at which the feed is digested slows and daily additions to the rumen are therefore decreased. These facts must not be ignored in fitting production functions. Data should be separated into two sets when the experiment involves diets that occur in the two different phases of intake regulation. If data are combined and an overall function is fitted, significant distortions in the isoquants and other relationships could result. A diagram of isoquants implied by our proposed framework is presented later.

General Technical Framework

Let the appetite of the ith animal, as it relates to calories per kilogram (energy concentration) of its diet, be described as

$$(1) \qquad Y_i = A_i/X + B_i,$$

where Y_i is the kilograms of daily voluntary dry matter intake (DMI) divided by its metabolic size ($W_i^{0.75}$), W_i is the body weight of the ith animal, and X is the calories per kilogram of the diet measured in terms of net energy for gain (NE_g).

Then, the daily intake of energy is DMI multiplied by dietary energy concentration:

$$(2) \qquad XY_i = A_i + B_iX.$$

Alternative algebraic forms (e.g., $Y = A'_i + B'_iX$ and $XY_i = A'_iX + B'_iX^2$) and implications for gain have also been tested (Brokken and Dinius 1974, 1976). There were no meaningful differences in the fit or in implications between the two sets of relationships.

By expressing net energy for maintenance (NE_m) concentration as a function of NE_g concentration in the California net energy system (National Academy of Sciences), their daily net energy requirements functions may be rewritten as

$$(3) \quad XY_i = 0.08089X - 0.03185X^2 + bg_i + cg_i^2,$$

where g_i is gain in kilograms per day (for steers, $b = 0.05272$ and $c = 0.00684$; for heifers, $b = 0.05603$ and $c = 0.01265$). Dividing equation (3) through by X, we obtain DMI requirements per unit metabolic weight in terms of dietary energy concentration and gain.

Equating equations (2) and (3) and solving for g_i,

$$(4) \quad g_i = -\frac{b}{2c} + \left[\left(\frac{b}{2c}\right)^2 + \frac{(A_i + B_iX + 0.03185X^2 - 0.08089X)}{c}\right]^{\frac{1}{2}}.$$

This system is diagrammed in figure 2. In chart C of figure 2 the curves for two animals are parallel. This implies that voluntary energy intake curves, chart D of figure 2, are divergent, which implies that performance of the animal with the higher potential for voluntary intake is affected by changes in dietary energy concentration more than animals of lower growth potential. The reader can follow through the implications of functions that converge in chart C in a manner to allow parallel curves in chart D.

How can the coefficients A_i and B_i be defined? What is the difference in voluntary DMI at a particular energy concentration between any of the ith animals ($i = 1, 2, \ldots, n$) and some arbitrary animal, say $i = 0$? Obtaining $Y_i - Y_0$ from equations (1) and (3), solve for $A_i/X + B_i$:

$$(5)\quad A_i/X + B_i = A_0/X + B_0 + \frac{b}{X}[g_i(X) - g_0(X)] + \frac{c}{X}[(g_i(X))^2 - (g_0(X))^2],$$

where $g_i(X)$, $i = 0, 1, 2, \ldots, n$, is a value for gain per day that is consistent with each value of X as in equation (4).[1]

A_0 and B_0 are estimated by directly observing Y_i for $A_i/X + B_i$, the rate of gain of each animal at each energy concentration for $g_i(X)$, and the mean gain of animals at each energy concentration for $g_0(X)$. To specify A_i and B_i, two additional hypotheses are required. Hypothesis I is the case of parallel appetite functions with corresponding divergent energy intake functions, i.e., $A_i = A_0$, $i = 0, 1, 2, \ldots, n$, and $B_i \neq B_0$. Hypothesis II is the case of converging appetite functions with corresponding parallel energy intake functions, i.e., $B_i = B_0$ and $A_i \neq A_0$. Obviously, other possibilities exist, but these two are convenient starting points and have quite different implications for the optimum dietary energy concentration for animals of different growth rates. These two hypotheses are illustrated graphically in figure 2 and for our numerical example in figure 3. It should be understood that while the foregoing arguments are couched in terms of differences between two individual animals, the important point of interest has to do with differences between animals of high gain potential as a group and animals of lower gain potential.

[1] The case where rate of gain declines throughout the feeding period was not encountered and remains to be worked out. Simulations of errors under conditions of other than a constant rate of gain showed only minor errors from the assumptions of constant (mean) gain over the entire period under most typical gain trajectories; usually from 0.1% to 1.0%. For the case of a substantial and long term decline or increase in gain per day, the assumption of constant gain may introduce substantial bias depending on the length of feeding period. In this case, we propose the following modification of equation (5): $Y_{ikt} = A_0 + B_0 X_k + \frac{b}{X_k}(g_{ikt} - g_{0k}) + \frac{C}{X_k}(g_{kit}^2 - g_{0k}^2)$, where k represents the kth level of energy concentration and t represents the tth feeding period.

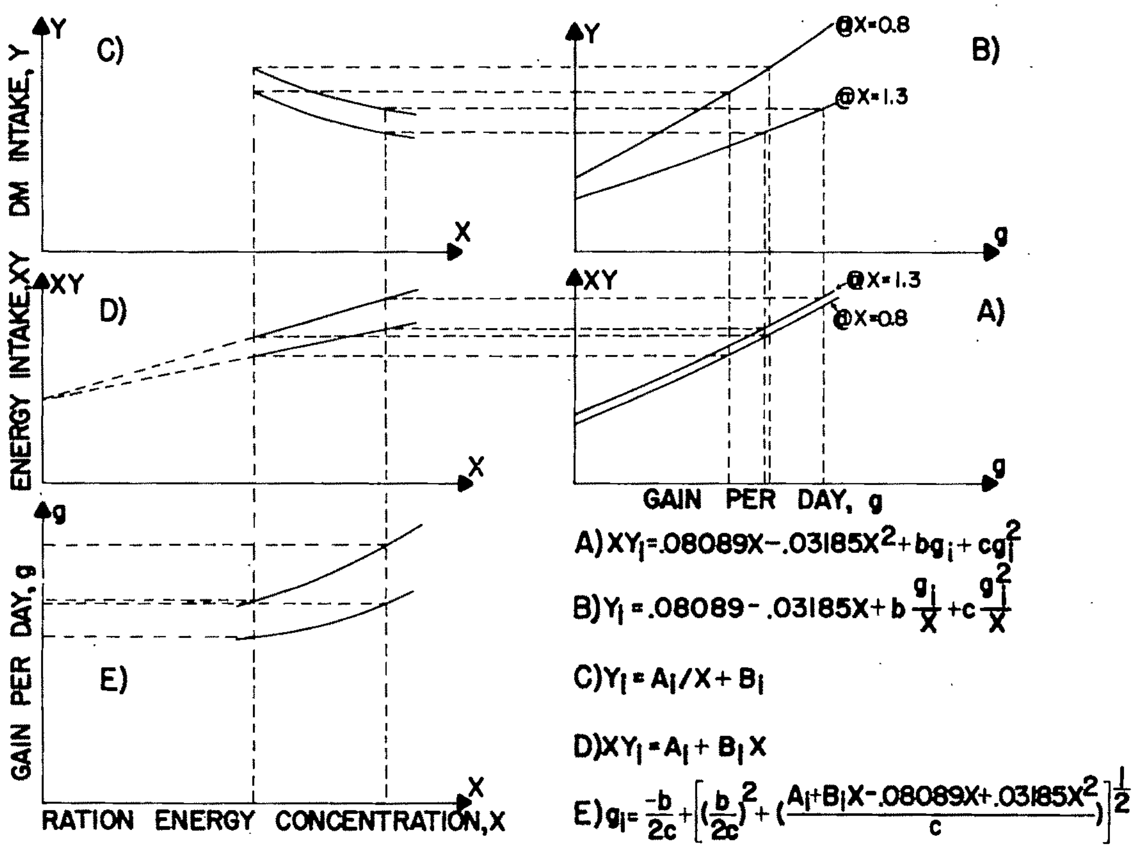
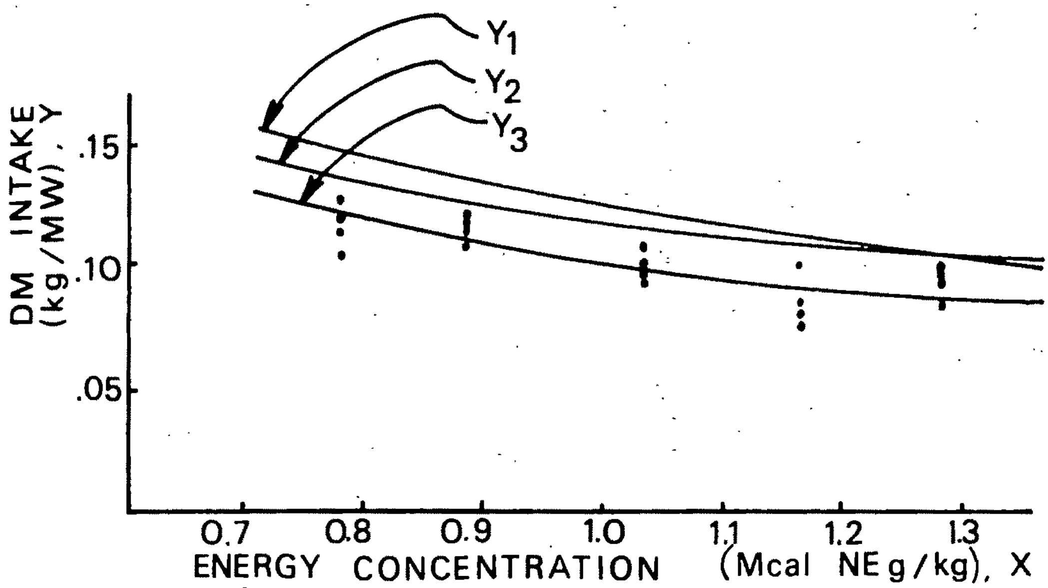
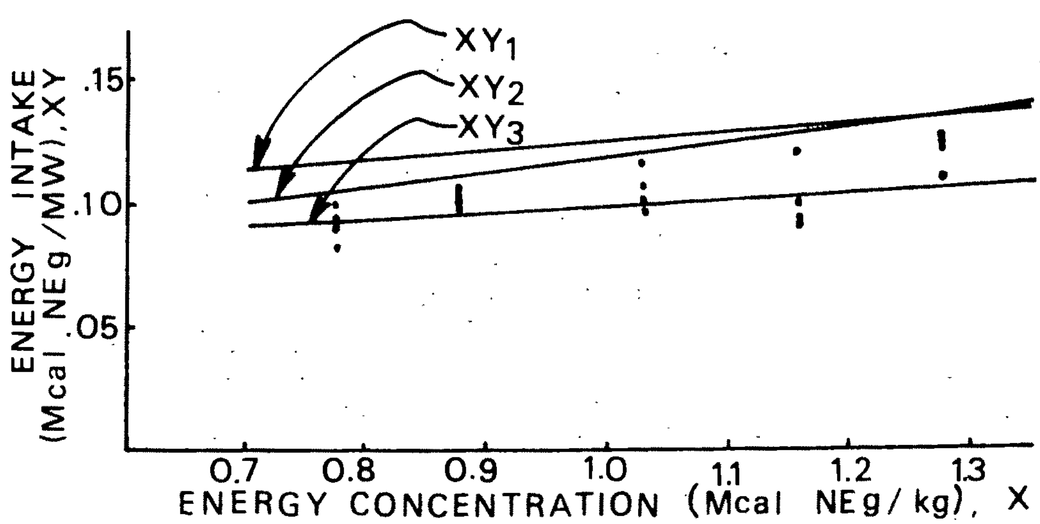


Figure 2. System of daily voluntary feed and energy intake and daily requirements for maintenance and gain in relation to dietary energy concentration



A. DAILY VOLUNTARY DM INTAKE



B. DAILY VOLUNTARY ENERGY INTAKE

Figure 3. **Daily voluntary dry matter and energy intake for three animals**

Needed Development

The case of calves versus yearlings is an interesting one in the context of different gain potential. Yearlings generally gain faster than calves in the feedlot. If appetite functions for yearlings and calves tend to be parallel (and voluntary energy intake functions divergent), then reductions of ration energy concentration will reduce energy intake and rate of gain in the yearlings more than in calves and their optimum diets may differ.

For the case of heifers versus steers, or the case exotics versus English breeds, the body energy parameters, b and c, of equation (3) must also be differentiated (the curves in charts A and B of figure 1 would be steeper for steers than for heifers and steeper for the English breeds than for the exotics). The heifers are likely to gain less per day than steers, but the energy per unit of their gain at any given body weight is greater. Therefore, heifers may consume as much or more dry matter per unit metabolic size per day but gain less weight than steers. The coefficients of net energy requirements for gain are differentiated for steers and heifers by the National Research Council (NRC) (National Academy of Sciences), but further differentiation is needed for bulls of the English breeds and for heifers, steers, and bulls of the large (exotic) breeds. The general appetite model equation (5) should also be separated by differentiating the energy parameters b_j and c_j for the jth class of animals. Corresponding adjustments throughout the system would follow.

In addition to differences in growth potential, several other factors affect parameters of the appetite functions. For example, it is known that stress reduces the appetite. Further, ration heat increment (HI) relative to NE_g is higher in roughages than in grain. Hence, we would expect the appetite function (figure 2, chart C) to be lower and flatter under heat stress than under a thermal neutral condition. Since practically no two ingredients have the same ratio of metabolizable energy (ME) to NE_g, two different blends with the same overall concentration of NE_g will have different ME concentration, therefore different heat increments. In fact, the relative HI of diet can be varied widely for any but the maximum level of NE_g concentration (Brokken 1971b; Lofgreen). In light of the newer interest in high roughage rations, more work is needed to establish optimum rations for hot and cold weather. Physical form of the ration (pelleted, flaked, high moisture, ground, etc.) also affects intake and the steepness of the appetite function (McCroskey et al., Cullison). Pelleting high roughage rations increased DMI but decreased it in high concentrate rations.

A great deal of work remains to be done on the subject of grain-roughage substitutions in cattle feeding. We believe this analytic framework offers improved coherence to the manifold factors involved and can serve as a basis for designing many additional feeding trials.

Perhaps a meaningful approach would be to develop a somewhat arbitrary standard set of relations for one type of animal under carefully controlled and described environmental conditions with carefully developed diets having a given set of nutrient-energy ratios, etc. Then as important deviations from the environmental conditions, physical form of the diet, etc., were studied, a set of operating rules could be developed to appropriately modify the standard functions so that the system applied better to conditions of a particular application. If sets of functions for different types of animals grown under the same conditions were significantly different, standard sets of functions with appropriate operating rules could be developed for different types of animals.

Three Animals

We now specify appetite and energy requirements functions for three animals. The reason for using three animals is to illustrate better the economic importance of some possible variations in the appetite functions and in the functions for daily energy requirements for maintenance and gain. The first animal represents the sample mean of animals in an experiment designed to estimate an appetite function and test the hypotheses of converging and parallel appetite functions. In this experiment (Dinius et al., Brokken and Dinius 1976), each of five diets varying in digestible energy (DE) from 3.605 to 2.804 million calories per kilogram were fed to four Angus and four Santa Gertrudis yearling steers. Corresponding NE_g values, derived from NRC formulas (National Academy of Sciences), varied from 1.28 to 0.778 million calories per kilogram. Protein-energy ratios were constant for all diets, and the environment was virtually free of climatic stress. Roughage used in the experiments was high quality hay, half alfalfa and

half orchardgrass. All rations were ground and fed as a complete mix. Other work corroborates these general findings but stops short of a framework for deriving parameters as a function of growth capability and for analyzing efficiency implications (Montgomery and Baumgardt 1965a, b; Dinius and Baumgardt).

It was established that though cattle will eat more pounds of the higher roughage rations per day, net energy intake is less than from rations of higher grain content. Appetite functions for faster and slower gaining animals were exactly parallel (hypothesis I) but statistically did not preclude convergence (hypothesis II). Actual mean feed (energy) intake levels and mean rates of gain are closely approximated by the derived functions of each of the five energy levels used in the experiment.

The hyperbolic appetite function that was derived from the experiment (Brokken and Dinius 1974, 1976) is used for animal 1:

$$(6) \qquad Y_1 = 0.0625/X + 0.04279.$$

Daily net energy requirement per unit of metabolic weight of the experimental sample is

$$(7) \qquad XY_1 = 0.05222 + 0.05412g_1,$$

where g_1 is the rate of gain for animal 1. Combining equations (6) and (7),

$$(8) \qquad g_1 = (XY_1 - 0.05222)/0.05412 = 0.18995 + 0.79065X.$$

While equation (7) predicted the energy requirements for the experimental sample of animals quite well, it was derived from a rather small sample (forty animals, twenty Angus and twenty Santa Gertrudis) and deviates significantly from NRC functions for maintenance and gain (National Academy of Sciences). On the other hand, the NRC functions have predicted animals' feed requirements and performance on high energy diets quite well in many commercial operations. These animals had to have appetite functions that passed through a point that was consistent with the feed (energy) intake described by the NRC function (equation (3)). Suppose the appetite functions for animals 2 and 3 are, respectively, convergent and parallel with the appetite function of animal 1. Suppose further when $X = 1.28$, both will gain three pounds per day (1.36 kilograms), then

$$(9) \qquad Y_2 = 0.08153/X + 0.04279 \text{ (converges to } Y_1\text{)},$$

$$(10) \qquad XY_2 = 0.08153 + 0.04279X \text{ (parallel with } XY_1\text{)},$$

$$(11) \qquad Y_3 = 0.0625/X + 0.05766 \text{ (parallel to } Y_1\text{)},$$

and

$$(12) \qquad XY_3 = 0.0625 + 0.05766X \text{ (diverges from } XY_1\text{)}.$$

To obtain $g_2(X)$ and $g_3(X)$ equate equations (10) and (12), respectively, to equation (3) and solve for g_2 and g_3 as in equation (4). The three appetite functions and corresponding voluntary daily energy intake functions are shown in figure 3.[2]

Total feed requirements over a span of time or weight gain can be calculated in several ways. The following method has proven useful with very low aggregation error under most gain trajectories. Feed intake on day t is

$$(13) \qquad YW_t^{0.75} = Y(W_0 + gt)^{0.75},$$

where W_0 represents the weight, when $t = 0$.

Total feed (TF) over n days is

$$(14) \qquad TF = Y\int_0^n (W_0 + gt)^{0.75}dt = \frac{Y}{1.75g}[(W_0 - ng)^{1.75} - W_0^{1.75}].^3$$

Weight on the nth and final day of the feeding period is $W_n = W_0 + ng$. Hence, total feed over the span of weight from W_0 to W_n is

$$(15) \qquad TF = \frac{Y}{1.75g}[W_n^{1.75} - W_0^{1.75}].$$

Both Y and g are functions of X; or, for a given X, Y can be expressed as a function of g.

Profit Function

Profit, π, is total revenue (TR) minus total cost (TC):

$$(16) \qquad TR = 0.96PW_n,$$

where P is market price and 0.96 is $1 - s$, where s is the shrinkage factor. Also,

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[2] The observation points for figure 3 are adjusted within each diet by $Y_i - 0.05412\,(g_i - \bar{g}_k)/X$ and $XY_i - 0.05412\,(g_i - \bar{g})$ for charts A and B, respectively. Without these within diet adjustments for differences in dry matter (energy) intake owing to within diet differences in gain, some of the observation points would lie well above the curves Y_2 and Y_3 in chart A and above XY_2 and XY_3 in chart B. Hence, all three examples developed here lie well within the intake observations of the experiment.

[3] In the case where feed intake per unit metabolic weight and gain per day decline continuously at a substantial rate, the integral should be broken up into a series of two or more segments of time or in the extreme, discrete summation day by day should be used.

(17) $$TC = (1 + rn)P_0W_p + \left(C_x + \frac{rnC_x}{2} + C_p\right)\frac{Y}{1.75g}(W_n^{1.75} - W_0^{1.75}) + nC_n + (1 + rn)K_1 + K_2,$$

where r is daily interest rate; n is $(W_n - W_0)/g$, the number of days in the feedlot; P_0 is purchase price; W_p is the payweight; Y is feed per day per unit metabolic weight; g is weight gain per day; C_x is the minimum feed cost per kilogram of feed for a given energy concentration with appropriate concentrations of other nutrients; C_p is feed preparation cost per kilogram of feed; C_n is yardage cost per day; K_1 is acquisition costs including commissions, trucking, vaccination, dipping, etc., and K_2 is fixed cost on equipment and facilities.

Under most custom feeding contracts, K_2 is treated as a variable cost and is included in feed preparation ("feed mark up") and yardage, i.e., in C_p and/or C_n. Such contracts discriminate slightly against adjustments to rations with lower energy concentration from the cattle owner's standpoint.

As a practical matter, it is difficult to define marginal revenue with respect to body weight or with respect to days on feed when price takes discrete jumps as slaughter grade changes or if market price is changing for any reason. Once the animal has reached the grade of Good, the marginal revenue from the grade of Good to Choice (MR_{G-C}) is

(18) $$MR_{G-C} = (P_C - P_G)0.96W_G + 0.96P_C(W_C - W_G),$$

where P_C and P_G are, respectively, the expected slaughter prices for Good and Choice, and W_G and W_C are, respectively, the expected slaughter weights for Good and Choice.[4] The returns from price spread between Good and Choice are often greater than the returns from weight added between the two grades. Hence, even though marginal cost exceeds the expected Choice slaughter price, it is often economic to continue feeding to Choice as both more weight and a higher price per pound are produced.

For most of the past thirty years it has been very economical to feed to Choice grade. The major exceptions have been in cases where $P_C < P_G$, owing to a negative time trend in the market or to the case where the animal will not achieve Choice grade for genetic reasons. While at any point in time $P_C > P_G$ for those animals that will achieve higher grades, several additional days of feeding are required to go through the Good grade to reach Choice.

In situations as in late 1974 when marginal cost exceeds expected slaughter price throughout most of the potential feeding period, the only source of profit is in developing a positive price spread between the slaughter price and the purchase price. When price spreads are positive, the optimum weight may exceed to point where marginal cost is equated with expected slaughter price. In this case, the optimum weight balances the losses from the weight added against the gains from price spread. This weight could occur at any point between where marginal cost equals expected market price and a point where further increases in weight are discounted in price. Marginal cost (MC) with respect to weight is[5]

(19)
$$MC = \partial(TC)/\partial W_n = \frac{rP_0W_p}{g} + (C_x + C_p)\frac{Y}{g}(W_n^{0.75}) + \frac{rC_xY}{3.5g^2}(2.75W_n^{1.75} - 1.75W_0W_n^{0.75} - W_0^{1.75}) + C_n/g + rK_1/g.$$

Marginal cost with respect to time is g times marginal cost with respect to body weight:

(20) $$\partial(TC)/\partial n = (\partial(TC)/\partial W_n)g.$$

Let W^* be the weight at which MC equals expected slaughter price discounted for shrinkage, i.e., where MC = $0.96P$:[6]

(21) $$W^* = \left[\frac{0.96P_g - rP_0W_p - C_n - rK_1}{(C_x + C_p)Y}\right]^{\frac{1}{0.75}}.$$

The value of n at the point where $0.96Pg = \frac{\partial(TC)}{\partial n}$, n^*, is

(22) $$n^* = (W^* - W_0)/g.$$

Because expected slaughter price is not marginal revenue, W^* cannot be construed as an

[4] Average market price (AP) of a pen of animals may be a continuous function of average pen weight: $AP = \Sigma\alpha_iP_i$, where P_i is market price of the ith grade and α_i, the proportion of animals in each grade, is a function of the average pen weight.

[5] Set $n = W_n/g - W_0/g$ in equation (17) to calculate MC.

[6] In calculation of W^*, the term for marginal interest on feed, the third term in the right hand side of equation (19) was dropped. This term complicates calculation of W^* enormously but has only a minor effect on its value.

optimum market weight. To develop an expression for the optimum market weight, we must express P in the numerator of equation (21) as a function of weight. The reader can sympathize with the difficulty of deriving such an expression or in solving it once it was derived short of an iterative approximation method. The present analysis is sufficiently served by numerically evaluating the profit function at different slaughter grades.

Elsewhere in this issue Wilson approaches the analysis of forage-grain trade-offs from the criterion of daily returns above feed costs. In our notation, his criterion is

$$\pi' = Pg - C_x Y W^{0.75}. \tag{23}$$

His analysis is quite legitimate from the point of view of selecting diets that will maximize profit per head per unit time and provides a different and complimentary perspective to the approach in this paper. However, negative daily returns in equation (23) will occur at approximately W^* or n^*, respectively, from equations (21) or (22). Since this criterion cannot deal with returns from price spreads, its use is limited to analysis of optimum diets under the criterion of maximizing returns per head per unit time.

Profit per Unit Time

Since costs are based on daily inputs, the costs and return per unit time are easily obtained. Average profit per day is π/n. Under full feedlot utilization, the criterion becomes profit per animal per day. The maximization of π/n without consideration of time preference occurs when (Dillon, p. 73)

$$\frac{\partial(TR)}{\partial n} - \frac{\partial(TC)}{\partial n} = \frac{TR - TC}{n}. \tag{24}$$

In contrast, profit per animal is maximized when marginal revenue equals marginal cost, i.e., when

$$\frac{\partial(TR)}{\partial n} - \frac{\partial(TC)}{\partial n} = 0. \tag{25}$$

Since a major part of the returns may be obtained from increasing price per pound by increasing quality grade, the weight at which a given animal is slaughtered may not vary between optimizing criteria. The greater difference might be in the time required to obtain that weight, though in many instances the different criteria would obtain the same diet also.

As long as feedlot capacity is under utilized, the focus of analysis tends to be on profit maximization per animal. However, even in the case of less than full utilization of feedlot capacity, there may remain the issue of profit per unit time for calves versus yearlings. Since yearlings are typically fed only about half as long as calves, the same profit per head would give a yearling feeding program about twice as much profit per head per unit time as a calf feeding program. A similar point applies to optimum market weights, e.g., the same profit per head for Good and Choice grades would imply greater profit per unit time at the lower grade. The same profit per head for two different diets implies greater profit per unit time for the shorter feeding period.

The degree to which profit per unit time is an issue and alters production from maximization of profit per head will vary from firm to firm and as market conditions vary from year to year and through the cattle cycle. It should be remembered that annual profits to the firm are to be maximized, and this is not necessarily consistent with maximization of profit per animal per unit time even in the case where the firm has no other enterprise. In any case, when profits are positive, the use of more roughage in the finishing stage fares better relative to high concentrate diets under the criterion of maximizing profit per head than under maximizing profit per head per unit time. The following analysis emphasizes the case of profits per head, but profit per head per unit time is also calculated.

Analysis

The profit function derived in the previous section is evaluated numerically for all three animals. Five different diets and two different market weights are used. The diets vary in NE_g concentration from 0.9 to 1.3 million calories per kilogram; the market weights (including a 4% arbitrary shrink) are 456 kilograms (1,005 pounds) grading Good and 475.2 kilograms (1,048 pounds) grading Choice.

Two sets of ration ingredient prices are used with one set of feeder calf and slaughter prices and one set of feed preparation, yardage, and fixed costs. The ingredient prices are those that prevailed in Eastern Nebraska in November 1974 and March 1975. Slaughter

Table 1. Ration Cost and Expected Average Gain for Three Animals by Ration Energy Concentration

Item	Ration Energy Concentration (MCal NE_g/kg) 0.9	1.0	1.1	1.2	1.3
Ration Cost[a] (¢/lb., 100% dry basis [% roughage])					
Nov. 1974	4.03 (53)	4.52 (42)	5.08 (33)	5.64 (23)	6.20 (16)
Mar. 1975	3.40 (53)	3.74 (42)	4.16 (32)	4.58 (23)	5.00 (14)
Average Gain (lb./day)					
Animal 1	1.99	2.16	2.34	2.51	2.69
Animal 2	2.64	2.71	2.80	2.91	3.04
Animal 3	2.46	2.58	2.72	2.88	3.05

[a] Eastern Nebraska quotations for Nov. 1974 and March 1975, respectively: corn, \$3.40 and \$2.75/bu., corn silage (at 6 bu. corn plus \$3/ton, 28% dry basis), \$23.40 and \$19.44/ton; alfalfa, \$55.50 and \$49.00/ton; mixed hay, \$46.00 and \$45.00/ton; soybean meal, \$10.50 and \$7.26/cwt; urea, \$10/cwt for both periods; salt and minerals, \$5.40/cwt for both periods.

prices are for Good and Choice animals in Nebraska in March 1975 with feeder calf prices of November 1974.

The first section of table 1 shows the total ingredient cost per pound and the approximate proportion of roughages for each ration, for both sets of ingredient prices. The second section shows the average rate of gain from beginning to end of the feeding period, g_i (different from payweight to payweight rate of gain, g'_i), for each of the three animals on each ration.

Feed preparation costs are C_p = \$3 per ton; yardage, C_n = \$0.04 per day; acquisition and start-up costs, K_1 = \$8.55; fixed costs, K_2 = \$14.80; annual rate of interest, 8%; purchase weight, W_p = 315 kilograms (694 pounds); purchase price, P_0 = \$30.80 per hundredweight; and market price is \$35.20 per hundredweight for Good and \$36.40 per hundredweight for Choice.

Profit and other variables calculated from equations (16) and (17) are shown in tables 2, 3, and 4, respectively, for the three animals under the five diets. Calculations using the March 1975 and November 1974 feed prices

Table 2. Animal I: Calculated Gains, Profits, and Related Variables by Ration and Slaughter Grade

Item[a]	Ration Energy Concentration (MCal NE_g/kg) 0.9		1.0		1.1		1.2		1.3	
	Good	Choice	Good	Choice	Good	Choice	Good	Choice	Good	Choice
g'_i (lb/day)	1.57	1.60	1.70	1.74	1.84	1.88	1.98	2.02	2.12	2.16
n (days)	198	221	182	203	169	188	157	175	147	163
With March 1975 feed prices										
π (\$/head)	−55	−51	−45	−40	−39	−33	−34	−27	−30	−22
BEPP (\$/cwt)	23.21	23.82	24.59	25.37	25.36	26.06	26.06	27.04	26.67	27.73
BEP (\$/cwt)	40.74	41.29	39.74	40.19	39.17	39.57	38.66	39.02	38.22	38.54
COG (\$/cwt)	62.86	61.82	59.61	58.57	57.77	56.73	56.72	55.08	54.71	53.67
π/n (\$/head/day)	−0.28	−0.23	−0.25	−0.20	−0.23	−0.18	−0.22	−0.15	−0.20	−0.13
With Nov. 1974 feed prices										
π (\$/cwt)	−83	−83	−74	−73	−70	−67	−65	−62	−61	−58
BEPP (\$/cwt)	19.40	19.50	20.54	20.79	21.19	21.53	21.77	22.19	22.33	22.83
BEP (\$/cwt)	43.50	44.29	42.65	43.36	42.16	42.83	41.73	42.36	41.32	41.91
COG (\$/cwt)	71.76	70.71	69.03	67.98	67.40	66.39	66.04	64.99	64.71	63.67
π/n (\$/head/day)	−0.42	−0.38	−0.41	−0.36	−0.41	−0.36	−0.41	−0.35	−0.41	−0.36

[a] g'_i is payweight to payweight rate of gain, n is number of days in feedlot, π is profit. BEPP is break-even purchase price given production costs and slaughter price, BEP is break-even slaughter price given production costs and slaughter price, COG (cost of gain) is total cost exclusive of purchase cost of animal divided by net weight added (payweight to payweight gain), π/n is profit/head/day.

Table 3. Animal II: Calculated Gains, Profits, and Related Variables by Ration and Slaughter Grade

Item[a]	Ration Energy Concentration (MCal NE_g/kg)									
	0.9		1.0		1.1		1.2		1.3	
	Good	Choice	Good	Choice	Good	Choice	Good	Choice	Good	Choice
g'_t (lb/day)	2.08	2.13	2.14	2.19	2.21	2.26	2.30	2.35	2.40	2.45
n (days)	149	166	145	162	141	156	135	150	130	144
With March 1975 feed prices										
π ($/head)	−34	−27	−33	−26	−33	−26	−33	−26	−31	−24
BEPP ($/cwt)	26.13	27.12	26.28	27.30	26.18	27.18	26.26	27.27	26.45	27.49
BEP ($/cwt)	38.61	38.96	38.50	38.84	38.57	38.91	38.51	38.85	38.37	38.70
COG ($/cwt)	55.95	54.91	55.59	54.55	55.81	54.78	55.63	54.59	55.17	54.16
π/n ($/head/day)	−0.23	−0.16	−0.23	−0.16	−0.23	−0.17	−0.24	−0.17	−0.24	−0.17
With Nov. 1974 feed prices										
π ($/head)	−58	−55	−60	−57	−63	−60	−64	−61	−63	−60
BEPP ($/cwt)	22.70	23.24	22.46	22.97	22.09	22.55	21.94	22.38	22.00	22.45
BEP ($/cwt)	41.05	41.62	41.22	41.81	41.48	42.09	41.58	42.20	41.53	42.14
COG ($/cwt)	63.86	62.82	64.41	63.36	65.24	64.19	65.57	64.52	65.40	64.36
π/n ($/head/day)	−0.39	−0.33	−0.41	−0.35	−0.45	−0.38	−0.47	−0.41	−0.48	−0.42

[a] See footnote of table 2.

are summarized, respectively, in the middle and lower parts of each table.

Using March 1975 feed prices, the high energy ration is most profitable (least unprofitable) for all three animals, and the Choice grade is the most profitable market weight for all rations given that feeding is going to take place. Of course, no losses would be encountered if feeding was not initiated in the first place. Because the beginning and ending shrinkage in weight can be spread over more time in going on from Good to Choice, the payweight to payweight gain per day (g'_t) increases as the number of days on feed and grade increases. Break-even purchase prices (BEPP) appear to be well below cost of producing yearling feeders. The March 1975 slaughter prices were quite low and have since risen well above the break-even market price (BEP), which would cover all costs at zero

Table 4. Animal III: Calculated Gains, Profits, and Related Variables by Ration and Slaughter Grade

Item[a]	Ration Energy Concentration (MCal NE_g/kg)									
	0.9		1.0		1.1		1.2		1.3	
	Good	Choice	Good	Choice	Good	Choice	Good	Choice	Good	Choice
g'_t (lb/day)	1.94	1.98	2.03	2.08	2.14	2.19	2.27	2.32	2.41	2.46
n (days)	160	178	153	170	145	161	137	152	129	144
With March 1975 feed prices										
π ($/head)	−38	−32	−36	−29	−35	−28	−34	−27	−31	−24
BEPP ($/head)	25.52	26.43	25.86	26.82	25.92	26.89	26.14	27.14	26.45	27.49
BEP ($/cwt)	39.05	39.44	38.80	39.17	38.75	39.12	38.59	38.94	38.36	38.69
COG ($/cwt)	57.34	56.30	56.55	55.51	56.38	55.35	55.85	54.82	55.12	54.09
π/n ($/head/day)	−0.24	−0.18	−0.24	−0.17	−0.24	−0.17	−0.25	−0.18	−0.24	−0.17
With Nov. 1974 feed prices										
π ($/head)	−63	−60	−63	−61	−65	−62	−64	−62	−63	−60
BEPP ($/cwt)	22.05	22.49	22.01	22.44	21.83	22.24	21.84	22.25	22.04	22.48
BEP ($/cwt)	41.55	42.16	41.57	42.18	41.68	42.31	41.66	42.29	41.51	42.12
COG ($/cwt)	65.45	64.40	65.52	64.47	65.90	64.85	65.84	64.79	65.34	64.30
π/n ($/head/day)	−0.39	−0.34	−0.41	−0.36	−0.45	−0.39	−0.47	−0.41	−0.49	−0.42

[a] See footnote of table 2.

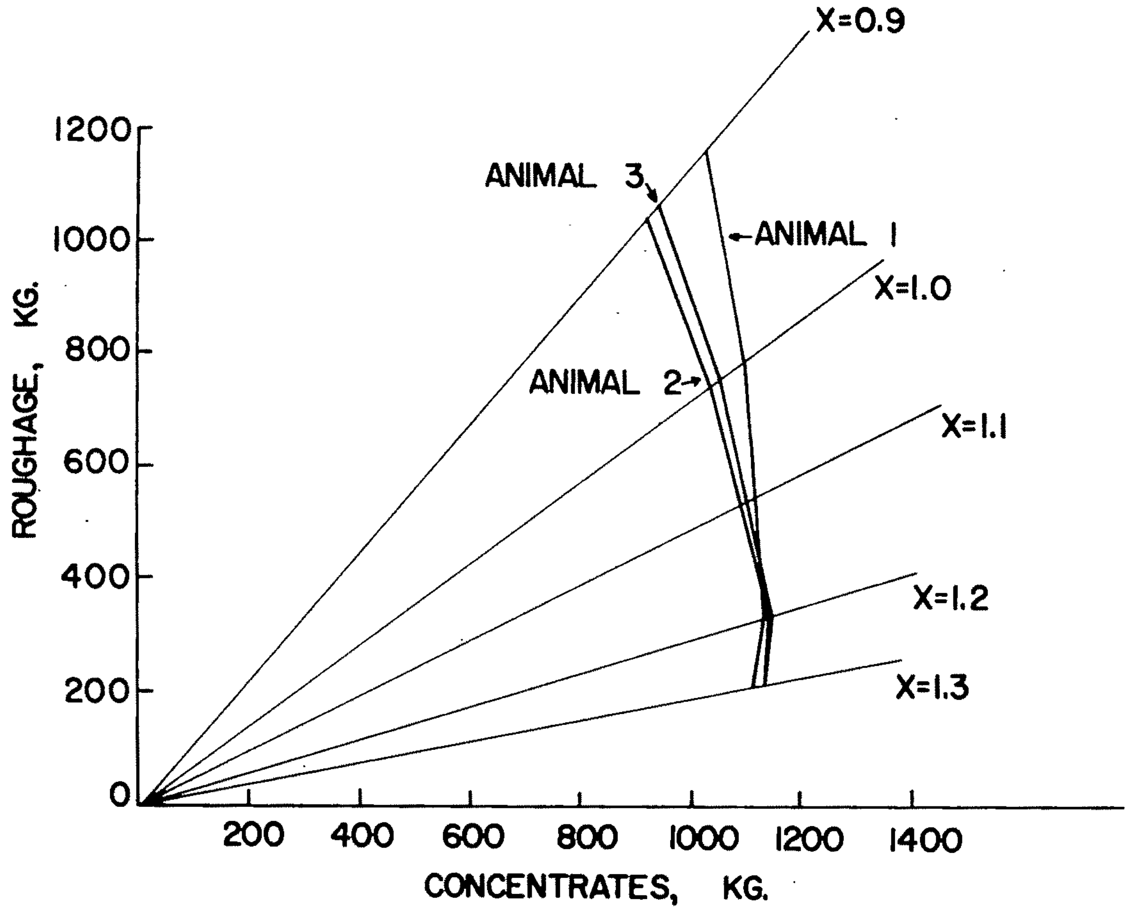

Figure 4. Isoquants derived from the appetite functions and feed requirements functions using diets of table 1 for animals 1, 2, and 3

profit given the purchase price of the animal and other costs. Average cost of gain, (COG), i.e., total cost of gain divided by total payweight to payweight gain, decreases as the fixed costs are spread over more weight added. The argument that feeding animals to heavy weights is wasteful is not supported by average COG calculations.

Corn prices were substantially higher in November 1974 than in March 1975. For November 1974 feed prices, the highest concentrate diet was still the most profitable for animal 1 (table 2). The Choice slaughter grade is the more profitable grade for all three steers in every case except for animal 1 with the high roughage diet where Choice and Good are equally profitable (rounded to the nearest dollar). However, the cost of gain and break-even prices show a small advantage for Choice grade in this case also. The price margin between Good and Choice used was only $1.20 per hundredweight. The optimum market weight remains unchanged over diets, even though the MC function increased as dietary energy concentration decreases. The issue in optimizing weight becomes feeding for price margin, i.e., feeding to obtain a higher price per pound by increasing quality grade. Further, the best diet for feeding to Choice grade is also the best one for feeding to any lower grade once the animal enters the feedlot. When cost of gain exceeds expected price per pound and price margins are positive, the strategy is not to sell at lighter weights but to buy heavier feeder cattle, thereby securing the revenue from price margin with a smaller expenditure of feed and time.

The low concentrate diet is the most profitable for animal 2, while for animal 3 profits were equal for the high concentrate and low concentrate diets. The fact that the optimum diet appears to swing from high concentrate to the low concentrate diet suggests a linear or concave isoquant for the roughage-

concentrate substitution relationship. Total profit divided by number of days on feed, π/n, is negative in every case. Maximizing profit per head per unit time seems a dubious criterion when it is negative. While the high roughage diet will give a lower average loss per day in some cases, one is committed to more days and a larger eventual loss per head. The criterion seems to make more sense in the case of positive profits.

Implied Isoquants

Isoquants strike a familiar chord with economists and can help to place many of the technical issues into clearer perspective. The authors believe that the technical aspects of the problem must be well understood by economists in order for them to serve well in further multidisciplinary research on this subject.

The implied roughage-grain isoquants can be plotted by connecting the coordinates for total roughage and total concentrates required in the production of an animal of a given final weight for each of the five diets. Total roughage (TROU) is

$$(26) \qquad TROU = q(TF),$$

and total concentrate (TCON) is

$$(27) \qquad TCON = (1 - k - q)TF,$$

where TF is taken from equation (14), q is the proportion of the ration that is roughage (table 1), and k is the proportion of nonenergy bearing ingredients such as salt, minerals, vitamin mix, urea, etc. These coordinates are plotted on figure 4 for each of the three animals. Notice that the isoquants are concave to the origin!

The data plotted represent only the upper range of ration energy concentration, i.e., the range where gut fill (distention) does not limit intake (see figures 1 and 3). For the implied roughage-grain isoquant to become convex to the origin, the appetite function must become much steeper than those found in this study or become steeper by taking the form of a function that is decreasing at an increasing rate. However, for the present sample, the hyperbolic function that decreases at a decreasing rate fits the data slightly better than the linear function.

In the low range of energy concentration where gut fill (distention) limits intake (see figure 1), our calculations showed that isoquants are convex to the origin for all likely appetite functions in this range, i.e., for all functions between a horizontal line and a 45° line through the origin that intersect with Y_1 (equation (6)) at $X = 0.78$. This evidence suggests we may expect S-shaped isoquants for many cattle feeding situations.[7] The shape of the isoquant is also affected by the many factors influencing the appetite function, which were cited earlier as needing further research.

The implications of concave isoquants for feeding trial experiments and feedlot management are important. For example, feeding trial experiments might focus only on the very high concentrate diets and on diets that approach the point where gut fill becomes the constraining mechanism on daily feed (energy) intake. Diets in between these two extremes are likely to be uneconomical relative to either extreme. This issue needs immediate further exploration from both hypothetical simulations and empirical experimentation.

Summary and Conclusions

It is suggested that much of the present confusion regarding the economics of cattle feeding and optimum rations is due to the inadequacy of traditional analytical frameworks for dealing with these complex issues. A technical system that relates cattle performance to ration nutrient concentration is developed by combining daily voluntary feed (energy) intake as function of ration energy concentration and animal weight (an appetite function) with daily feed (energy) requirements for maintenance and growth as a function of rate of gain and animal weight. The system appears very promising for assessing the efficiency of animal production under a wide range of diets and production circumstances for different types of cattle. The experiment and the analytical framework on which the economic analysis rests need to be expanded to cover more situations known to affect the voluntary feed and energy intake.

A dynamic profit function that incorporates the daily performance functions is developed and an economic analysis for three different animals is made. Results of this analysis show

[7] John T. Scott, Jr., called our attention to slightly concave isoquants indicated in the work of Goodrich et al. This article is based on data from seventeen midwestern university experiments, in which rations of varying proportions of corn silage and corn were tested.

that high energy rations remain optimum under rather high grain prices in many cases.

In an important sense, the conclusions based on this model are conservative. The ratios of roughage to grain prices used are lower than what exist in many regions. Including fixed costs in variable costs as "feed mark-up" or "yardage," a common practice in custom-feeding contracts, discriminates against high roughage diets. Fixed costs were separated from variable costs in this analysis. Price spread between Good and Choice was very small. The appetite function for animal 2 favors roughage most, but is the least consistent with the experimental results. Finally, profit per head was considered rather than profit per unit time.

The most surprising result is that the roughage-grain isoquant implied from the system is concave to the origin over the high energy range of feedlot diets and convex to origin on low energy diets. This result seems plausible in light of the probable shapes of the appetite functions and feed transformation function. Failure to recognize the potential for S-shaped or sigmoid isoquants may have distorted the results of some previous work.

Our main conclusions are that this important issue is complex and remains unresolved, that establishing a coherent set of experiments and data for general analysis of this problem remains a challenge, and that the analytical framework presented here is useful in addressing this challenge.

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National Food Policy for an Interdependent and Uncertain World (Luther Tweeten, Oklahoma State University, Chairman)

Do We Need a National Food Policy?

H. S. Houthakker

The title of this paper was changed from the one that the organizers gave me not merely because of a dislike of prolixity but also for more substantive reasons. The original title was "Do Consumers or the Nation Need a National Food Policy?" It reflected the division of labor between Seevers and myself, with his speaking about food policy from the producer's point of view. I recognize, of course, that there is a producer's point of view, and I have no doubt he will give it adequate weight. Nevertheless, I feel that if we, that is, the consumers, do not need a national food policy, then it is not likely that producers are justified in asking for one.

To say that national policies have to be oriented towards consumers rather than producers may betray a total lack of political sensitivity. We all know that policies for particular industries, be it energy, transportation, or steel, are generally initiated and supported by producer interests. However, this paper deals with policy rather than politics, and approaches the subject from an economist's point of view. That point of view, by and large, is a consumer's point of view.

By way of further introduction, let me say something about the notion of a national policy without regard to its subject. Consider the industry that economists have studied most thoroughly, the widget industry. If someone calls for a National Widget Policy, we can be sure that he wants the government to do something. Doing nothing is not generally considered a policy, even though it may be the best approach the government can take. Furthermore, to be worthy of the name, a National Widget Policy would have to have some degree of internal consistency; a panoply of contradictory measures presumably could not be described as a national policy.

It follows that the desirability of a National Widget Policy should be judged against two alternatives, one being government abstention) the laws and regulations remained in sures. It is the latter alternative that people usually have in mind when they call for a national policy. The very nature of the political process makes it inevitable that government intervention in any industry is beset by contradictions. Many government measures were originally motivated by immediate problems, but even after these problems had disappeared (whether or not as a result of government action) the laws and regulations remained in force. An important reason for this persistence of obsolete programs is that each of them has usually acquired a constituency of its own. A major effort is therefore needed to get rid of government programs that have outlived their usefulness. Nevertheless, it can be done, as the abolition of the sugar program in 1974 shows.

In the area of food policy, there are also many contradictions. Although the price support programs for basic crops are no longer effective, certain other agricultural programs continue to raise food prices. This is especially true of federal and state marketing orders and of import restrictions on dairy products and meat. Offsetting these producer-oriented programs, there are others, such as food stamps and the school milk and school lunch programs, that tend to lower prices. These contradictions bring us back to the other alternative to a national food policy, namely, abstention from government intervention.

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The Justification of Government Intervention

Whether the government can abstain from intervening in food matters depends primarily on the effects of unfettered operation of the market mechanism and more particularly on the effects on consumers. The question is whether the free market can produce adequate food supplies at reasonable prices. It need hardly be said that the terms "adequate" and "reasonable" are imprecise, but that is no reason for ignoring the question. The interpretation of these terms is essentially a matter of political judgment. In present circumstances food supplies will only be considered adequate if all, or virtually all, consumers are able to maintain a diet that meets certain nutritional standards.

In other words, there should be no involuntary malnourishment among domestic consumers. Two adjectives in this sentence need emphasis: "involuntary" and "domestic." The first refers to the well established fact that even in some high income households diets are insufficient by these nutritional standards because of "dieting" or ignorance; this is clearly not an economic problem but rather (if it is a problem at all) an educational one. As regards the restriction to domestic consumers, while there are certainly people who are concerned about the adequacy of nutrition in other countries, it can hardly be said that there is a national consensus to this effect. In fact, the maintenance of nutritional minima on a global scale would be a staggering task and would raise serious questions of population policy.

At first sight, government intervention in individuals' food purchases may appear to be in conflict with consumers' sovereignty, a notion dear to economists' hearts. Why not let households buy as much or as little food as they want at prices reflecting the social cost of production? If households cannot buy enough food because of poverty, the answer would be income supplements rather than subsidies linked to specific expenditures.

These are weighty, and generally valid, considerations. Nevertheless, there are good grounds for not relying entirely on the response of households to market forces. In particular there is reason to fear that in families with low food consumption the children are at a special disadvantage, not merely in their current intake but, more importantly, in that their physical and intellectual development may be stunted. To the extent that these children are in schools, they can be reached by such programs as school lunches and school milk. The problem of preschool children, however, is inherently more difficult; indeed, it is the most compelling, not to say the only valid, justification for government intervention. The situation here is similar to that in education, where parents also cannot always be counted upon to make socially optimal investments in the human capital of their children.

The principal drawback of government programs to improve nutrition by food subsidies is that they may be made available to many people who could perfectly well take care of their own nutrition. This danger is all the more real because food programs, while ostensibly directed at consumers, often derive some of their political support from producers anxious to expand their markets. Despite this danger, the microeconomic justification of these programs is not open to serious question.

Another argument for government intervention in the food markets is based on the relative volatility of food prices, which are strongly affected by the weather and by variations in demand (especially from abroad). There is little doubt that this volatility makes life difficult for producers, who are often unable to protect themselves (by hedging or forward contracts) against sudden falls in output prices or rises in input prices. Greater price stability can therefore promote efficiency in food production, which also benefits consumers provided there is active competition. It is not equally clear that price stability provides any other advantages to consumers. Nevertheless, rises in food prices—especially in highly visible meat prices—are very unpopular, although price falls are barely noticed. From a political point of view, stabilization of food prices therefore is generally desirable.

The Demand for Food in the United States

Although there is justification for some degree of government intervention in food consumption, the extent of this intervention should depend on the general performance of the food markets. To correct particular problems, such as occasional malnutrition or excessive price instability, is one thing, but to view these markets as unable to function without official

direction is quite another thing. Market performance is determined in part by the responsiveness of supply and demand to price changes. In a well functioning market, prices have to adjust frequently in order to even out fluctuations in supply and demand caused by exogenous determinants, whereas in a malfunctioning market prices tend to be rigid while supply and/or demand fluctuate sharply.

A detailed evaluation of the performance of the food markets, which would require an examination of the supply side, is beyond the scope of this paper. Let us just recall that numerous studies have found the price elasticity of food supply to be significantly positive, at least after sufficient time for adjustment. (See, for instance, Tweeten and Quance.)

On the demand side the evidence is not as clearcut, especially where food as a whole is concerned. In Houthakker and Taylor, for instance, a number of demand equations for food are reported, but prices were not significant in several of them. These equations were based on aggregate time series for the period 1929–64 (or sometimes 1947–64), and one reason for the insignificance of prices may have been that until the 1970s the relative price of food as a whole did not vary much because of price support programs. A variable with a small variance is not likely to be picked up by regression analysis.

With the gradual termination of these programs, food prices became more volatile, a development reinforced by the gradual disappearance of surplus stocks. For most of the 1950s and 1960s the Commodity Credit Corporation held large inventories, but they were reduced by such events as the failure of the Indian monsoon in 1966, the corn blight of 1970, and finally the Russian grain deal of 1972. In the last few years inventories in the United States (and hence, for most practical purposes, in the world) have been uncomfortably small, a matter further discussed below.

It is an ill wind that blows nobody any good, and the inflation of 1972–74 together with the recession of 1974–75 produced a great deal of potential information concerning the effects of price and income changes. Moreover, there are now quarterly national accounts data on consumers' expenditures on food and beverages at current and constant prices for the period 1953–75.[1] These show a rise of more than 12% in the relative price of food starting in late 1971 and continuing through early 1974. Per capita food consumption, which of course is also affected by income, fluctuated irregularly during the first half of the 1970s, with a marked decline in 1973 when the relative price was rising most steeply.

Various linear and double-logarithmic equations have been fitted to quarterly data from 1953 through the second quarter of 1975. There is not much to choose between these equations; the following appears to be the most useful.

$$
\begin{aligned}
(1)\quad \ln q_t = {} & -\underset{(-6.4)}{0.554} + \underset{(5.4)}{0.457}\ln q_{t-1} \\
& + \underset{(6.5)}{0.181}\ln y_t - \underset{(4.5)}{0.139}\ln p_t, \\
& \bar{R}^2 = 0.982;\ DW = 1.72,
\end{aligned}
$$

where ln is the natural logarithm, q_t is per capita food consumption at 1958 prices in period t, y_t is per capita personal disposable income, deflated, and p_t is the relative price of foods as defined in note 1. The t-ratios are given in brackets; they are satisfactorily large. This equation implies an income elasticity of 0.18 in the short run and of 0.33 in the long run. The price elasticity is -0.14 in the short run and -0.26 in the long run.[2] Although fairly small, the price effects are quite significant from a statistical point of view and also important for the subject of this paper, since the performance of a free market depends in part on the responsiveness of the demand side to price changes.

The Demand for Food Abroad

Since the United States is a major food exporter, the price of food in this country is heavily influenced by foreign demand. It is therefore of interest to estimate the price elasticity of food demand abroad. A comprehensive analysis would meet with serious data problems, but valuable insights can be obtained by looking at a few countries for which comparable data are available for a sizable number of

[1] From now on, the term "food" will tacitly include beverages. The absolute price of food was calculated by dividing the constant-dollar expenditure into the corresponding current-dollar figure; the same was done for consumers' expenditure on all items. The relative price of food is the ratio of these two implicit deflators.

[2] These long-run elasticities are considerably smaller in absolute value than those estimated from annual data in Houthakker and Taylor. Although the model used there was linear rather than double-logarithmic, this does not appear to account for the discrepancy, which may be related to a defect in the dynamic specification of the underlying model of consumer behavior.

years.[3] The time series for these countries were pooled, that is, the same regression coefficients were assumed to apply to all countries; the intercepts, however, were allowed to differ so as to absorb currency and other statistical differences. The counterpart of equation (1) for the seven countries is

$$(2) \quad \ln q_{it} = a_i + \underset{(12.1)}{0.756} \ln q_{it-1} + \underset{(3.9)}{0.155} \ln y_{it} - \underset{(-1.4)}{0.130} \ln p_{it}, \qquad \bar{R}^2 = 0.986,$$

where the variables are the same as in equation (1), except for the additional subscript i indicating the country. The intercepts a_i are not relevant for the present purpose and have therefore not been calculated; the squared correlation coefficient from pooled time series does not have a straightforward interpretation and is given only for completeness.

In comparing equations (1) and (2), it should be borne in mind that equation (2) is based on annual data. The short-run elasticities with respect to income and price (here, 0.16 and −0.13, respectively), while apparently similar to those in equation (1), do not mean the same; in fact, to be consistent with equation (1) the short-run elasticities in equation (2) would have to be three or four times as large. The long-run elasticities, which are 0.63 for income and −0.53 for price in equation (2), are conceptually comparable with those in equation (1), but much larger. Actually what matters here is not so much whether the elasticities are different in the United States from those abroad but whether the price elasticities are significant. In this respect, equation (2) leaves much to be desired since the t-ratio for p_{it} is only −1.4. A better equation is

$$(3) \quad \Delta \ln q_{it} = a'_i + \underset{(5.8)}{0.340} \Delta \ln y_{it} - \underset{(5.2)}{0.534} \Delta \ln p_{it}, \qquad \bar{R}^2 = 0.351,$$

where Δ is the first-difference operator and the intercepts a'_i now represent the residual trends prevailing in each country. The lagged dependent variable is absent from equation (3), so an interpretation in terms of short and long run is no longer possible. Although the discussion in Houthakker (1965) suggests that equation (3) reflects primarily short-run effects, the estimated elasticities in equation (3) are actually closer to the long-run elasticities implied by equation (2). This implies once more that the dynamic assumptions underlying these equations need further examination.

Composition of Food Consumption

Notwithstanding these problems, it seems fair to conclude from the econometric analysis that the demand for food is responsive to price changes. It is also important to know whether the pattern of food consumption depends on prices, for it is sometimes maintained that the industrialized countries are inexorably bent on consuming more meat and other livestock products in lieu of crop products. Since grain fed to livestock produces fewer calories for human consumption than grain products consumed directly (for instance, in the form of bread), this allegation would imply that the rich countries, by insisting on meat, are causing starvation in the poor countries. While a full investigation of this question would lead us too far afield, it is interesting to see what has happened in recent years to the balance between livestock products and crop products.

This is done in table 1, which breaks down calories and proteins per head per day into crop products and livestock products for those OECD countries, not all of them highly industrialized, for which data for 1955–59, 1965–69, and 1973 are available.

Inspection of table 1 confirms the almost universal shift towards livestock products, but in many countries consumption of grain products (as measured by calories) also went up. In fact, most countries witnessed an increase in total calorie intake per head; it is especially pronounced in what were (and sometimes still are) the poorer countries: Italy, Japan, Por-

[3] Data were taken from the Organization of Economic Cooperation and Development, *National Accounts of OECD Countries*. (The most recent printed version covers the years 1962–73, but data from 1960 on were used here.) These data cover not only food and beverages but also tobacco. For seven countries (Australia, Belgium, Canada, Finland, Germany, Italy, and Japan), data were available for the entire period 1960–73, and these were the countries used here. The variables used are generally the same as in the U.S. analysis (see note 1), except that personal disposable income had to be calculated from "current receipts of households" by subtracting direct taxes on income and social security contributions; it was deflated by the implicit deflator for total consumption. Midyear population figures were taken from *International Financial Statistics*. Despite standardization by OECD, conceptual differences among the national accounts data of different countries are inevitable but believed to be minor. In two cases, missing observations had to be obtained from national sources.

Table 1. Calories and Proteins by Source

		Calories Derived from			Proteins Derived from		
		Crop Products	Livestock Products	All	Crop Products	Livestock Products	All
Austria	1955–59	1994	1167	3161	42.9	44.2	87.0
	1965–69	1915	1347	3262	36.4	51.5	87.9
	1973	1932	1400	3332	33.9	53.9	87.8
Belgium-Luxemburg	1955–59	1926	1162	3088	41.7	46.8	88.5
	1965–69	1927	1314	3241	37.6	52.6	90.2
	1973	1980	1461	3441	37.7	58.6	96.3
Canada	1955–59	1714	1288	3003	31.0	60.9	91.9
	1965–69	1800	1274	3074	30.4	63.7	94.1
	1973	1901	1257	3158	30.9	65.0	95.9
Denmark	1955–59	1885	1365	3250	32.7	51.3	83.9
	1965–69	1677	1526	3203	28.2	59.3	87.5
	1973	1634	1595	3229	26.7	65.5	92.2
France	1955–59	1992	1086	3078	47.3	51.1	98.4
	1965–69	1886	1294	3180	39.6	64.0	103.6
	1973	1879	1340	3219	35.7	67.0	102.7
Germany	1955–59	1920	1199	3119	38.1	45.0	83.1
	1965–69	1784	1347	3131	31.8	53.1	84.9
	1973	1821	1417	3238	30.5	57.5	88.0
Ireland	1955–59	2083	1323	3406	49.3	50.4	99.7
	1965–69	1955	1413	3367	41.7	58.7	100.4
	1973	1891	1488	3379	38.2	62.3	100.5
Italy	1965–69	2062	484	2546	53.2	28.0	81.2
	1965–69	2379	648	3027	56.2	40.0	96.1
	1973	2533	810	3343	56.4	48.9	105.3
Japan	1955–59	2052	162	2214	43.4	15.1	68.5
	1965–69	2103	349	2452	51.5	24.9	76.4
	1973	2089	482	2571	49.0	32.2	81.2
Netherlands	1955–59	2066	1049	3115	36.3	50.2	86.5
	1965–69	2005	1190	3195	31.9	54.1	86.0
	1973	1981	1195	3176	30.9	57.0	88.8
Norway	1955–59	2151	899	3050	36.1	51.0	87.1
	1965–69	1704	1267	2970	31.5	55.6	87.1
	1973	1712	1299	3011	30.4	54.6	85.0
Portugal	1955–59	2107	454	2560	48.9	25.1	74.1
	1965–69	2444	553	2997	56.2	32.0	88.2
	1973	2578	719	3297	54.2	39.0	93.2
Spain	1955–59	2100	365	2465	52.2	22.3	74.5
	1965–69	2048	562	2610	45.1	35.1	80.2
	1973	2097	732	2829	44.3	45.9	90.2
Sweden	1955–59	1737	1233	2970	30.8	55.5	86.3
	1965–69	1667	1174	2841	27.5	56.1	83.6
	1973	1640	1120	2760	26.3	57.6	83.9
United Kingdom	1955–59	1950	1227	3178	37.7	51.5	89.1
	1965–69	1848	1323	3171	34.8	55.2	90.0
	1973	1860	1270	3130	33.3	54.6	87.9
United States	1955–59	1806	1350	3156	32.2	67.1	99.2
	1965–69	1925	1307	3232	31.2	70.8	102.0
	1973	2040	1276	3316	31.0	72.6	103.6
Yugoslavia	1955–59	2311	559	2870	66.3	22.7	89.0
	1965–69	2581	608	3190	69.8	24.9	94.7
	1973	2484	680	3164	64.3	28.6	92.9

Source: Organization for Economic Cooperation and Development, 1975a (final table on each set of country pages). Protein is in g./head/day.

tugal, Spain, and Yugoslavia. The shift towards livestock products implied an increase in protein consumption in the large majority of countries, though in most of them protein consumption has stayed well below the U.S. level.[4]

[4] According to the spring 1965 Household Food Consumption (USDA 1965–66), the average protein consumption of American

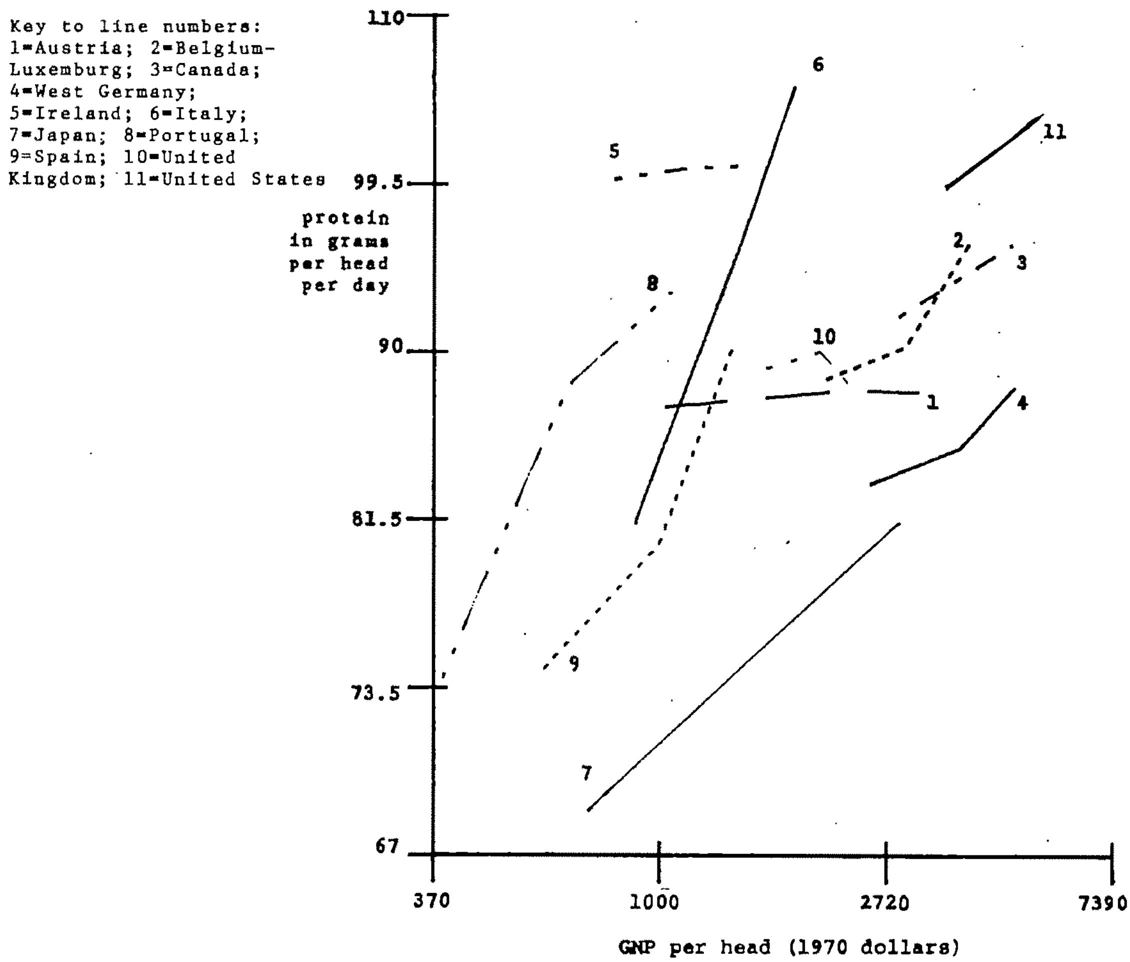

Figure 1. Protein consumption in relation to GNP per head

In figure 1, the data on total protein consumption from table 1 are plotted against per capita GNP in 1970 dollars at 1974 exchange rates.[5] Each of the eleven lines links the three observations for one country, and both variables are on a logarithmic scale. While the dispersion is considerable, some tendency towards a flattening towards the right-hand side of the chart can be detected; generally, the slopes are steeper for the low income countries at the left, except for Ireland, where protein consumption was high throughout the period of observation.

It is too early to say whether the increase in protein consumption is indeed slowing down, and these data also shed little light on the effect of relative price changes on the composition of food consumption. Pending further evidence, the worries about the effects of increasing consumption of livestock products on world nutrition can therefore not be dismissed lightly.

Nutrition in the United States

Let us now turn to the most important concern that a national food policy is intended to deal with, namely, domestic malnutrition. Detailed statistical evidence on this problem is available mostly from the 1965–66 Household Food Consumption Survey, which shows, not surprisingly, that malnutrition is associated with low incomes. However, some malnutrition is also found among higher income households.

households with incomes over $15,000 was 113.7 g.; the average for all households at that time was 105.8 g.

[5] The GNP (or in some cases Gross Domestic Product) was used instead of personal disposable income because otherwise too many countries would have dropped out for lack of consistent data; even so, six of the seventeen countries in table 1 could not be included in the chart. Exchange rates for 1974 were used because the adoption of floating in 1973 probably made them more realistic than in previous years.

Table 2. Percent of Households with Various Dietary Deficiencies

		% of Households with Less than Recommended Allowance		
Income Group	Number of Households in Sample	In One or More Nutrients	In Three or More Nutrients	Two-Thirds Less In One or More Nutrients
Under $3,000	1697	63	22	36
$3,000–4,999	1515	57	17	24
$5,000–6,999	1756	47	14	18
$7,000–9,999	1360	44	10	12
$10,000 and over	790	37	10	9

Source: As in note 4, pp. 5, 6, 14.

The adequacy of nutrition was measured in this survey by converting observed consumption of a large variety of foodstuffs into nutrients by a standard formula and comparing the calculated nutrient consumption with the recommended allowances of seven important nutrients (protein, calcium, iron, vitamin A value, thiamine, riboflavin, and ascorbic acid); there was no physical examination of the households' members. No attempt could be made here to verify the validity of these allowances or of the methods by which they were compared with actual consumption. No doubt these survey data are also subject to sampling fluctuations and to systematic biases inherent in household surveys, especially if they extend only over one week, as was the case here.

Table 2 gives some overall measures of the nutritional adequacy of household diets by income group. The correlation with income is evidently close. Further examination shows that three of the seven nutrients, namely, calcium, vitamin A value, and ascorbic acid (vitamin C) are particularly likely to be below the recommended allowance. For two of those (calcium and ascorbic acid), this is shown graphically in figure 2; the pattern for vitamin A is somewhat intermediate between the two shown. In figure 2, the full bar indicates the percentage of households that fall short of the recommended allowance, while the cross-hatched part gives the percentage of those who do not even reach two-thirds of the allowance.[6]

[6] Another report in the same series (no. 17) relates dietary adequacy to per capita expenditure on food. Although $5 per person per week was theoretically sufficient to meet all recommended allowances at the time of the survey, three-quarters of the households who spent between $5 and $7 per week were deficient in at least one nutrient. Even of households spending between $12 and $16 per week, one-quarter did not meet all recommended allowances. Sampling errors aside, this suggests that many households either do not agree with these nutritional requirements, or that they consider other aspects of food (such as palatability and variety) more important.

Malnutrition and Market Imperfection

Is it a coincidence that the three nutrients in which dietary deficiencies are most common are also the ones for which the market is least perfect? The principal source(s) of calcium is milk and of vitamins A and C are fresh fruits and vegetables, in addition to citrus juices. These are precisely the commodities for which marketing orders have long been used to restrict competition among producers. In the case of dairy products, where important restrictions are an additional barrier to competition, the main effect of marketing orders is to prevent, or at least severely limit, interregional flows of milk from undercutting local milk producers. Dairy cooperatives have organized so-called superpools to strengthen their market power, and their exercise of political pressure can without exaggeration be called scandalous. That their practices place a heavy financial burden on consumers is well known but that artificially high milk prices are also a major cause of malnutrition appear to be less widely realized.[7]

In many fruits and vegetables, marketing orders, reinforced by the antitrust exemption of farm cooperatives, are being used to restrict supply; California oranges and Florida tomatoes are two examples among many. Since production of specialty crops is often confined to one or a few small areas, supply control is not difficult to achieve, provided the government is willing. Destruction of so-called surpluses, whether before or after harvest, is a common practice in certain treecrops. Admittedly, there are special problems in the marketing of perishable fruits and vegetables

[7] The dairy interests sometimes claim in defense that many dairy farmers are poor. If so, one major reason appears to be that low-cost dairy producers are not permitted to sell in their best markets.

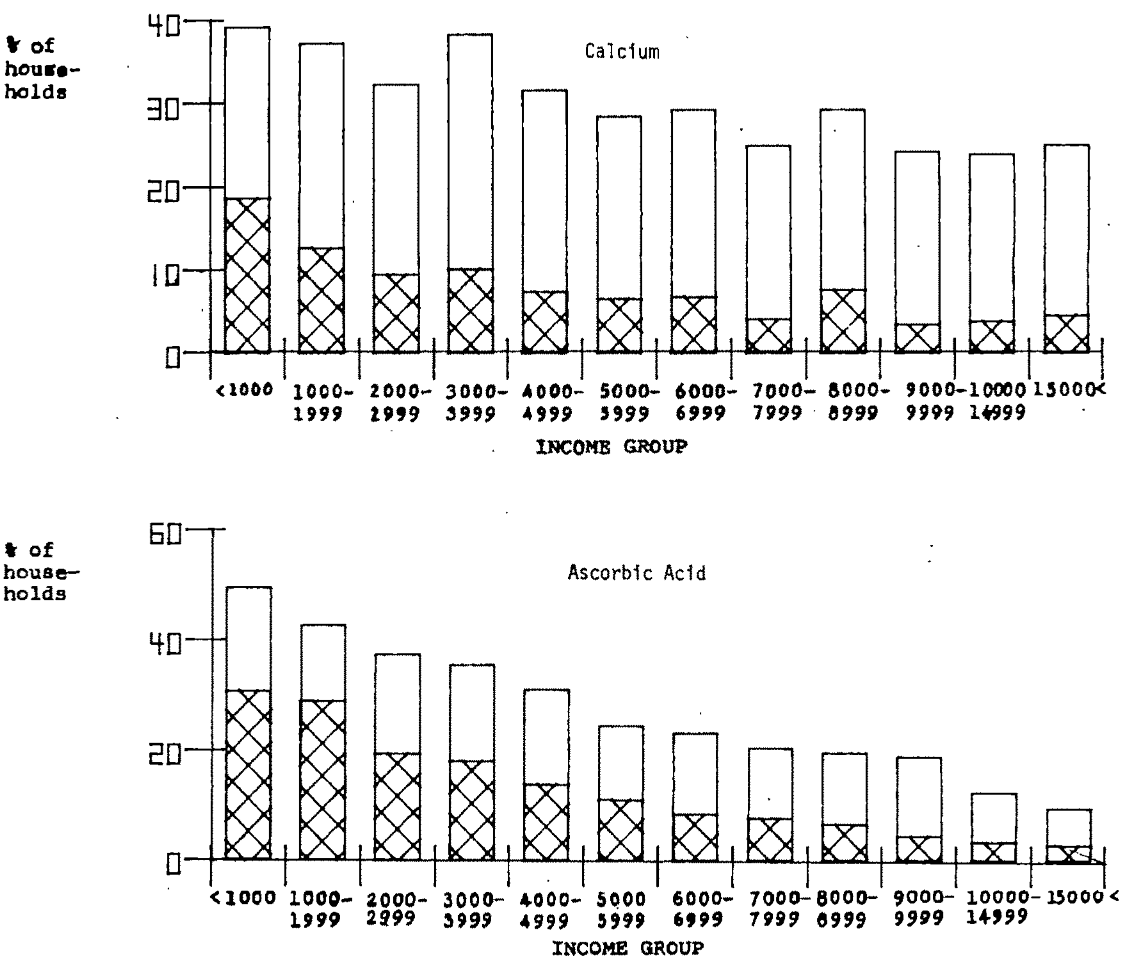

Figure 2. Nutritional inadequacy

when the bulk of the crop becomes available in a short period of time, but that does not justify government intervention at the expense of consumers.

The Food Stamp Program

After this digression from the main subject of this paper, it is time to go back to the consumer. In recent years the main activity of the Federal government on behalf of consumers has become the food stamp program. From a small start in the early 1960s it has been expanded in stages, and at present involves budget expenditures at an annual rate of well over $5 billion; the number of beneficiaries is now approaching twenty million. Originally intended mostly to increase the demand for food, it has now become one of several overlapping programs to counteract poverty.[8] Under this program eligible households are entitled to stamps that can be used like money in the purchase of domestic foodstuffs and certain inputs into food production. Eligibility is determined by income and family size, and these factors also determine how much participating households must pay for the stamps. Thus, in early 1975 a four-person household was entitled to stamps with a face value of $154 per month, for which it would pay nothing if its net money income was below $30 per month, $53 at an income of $200 per month, and $130 at an income of $500 per month. Four-person households with monthly incomes over $513 were not eligible.

The program therefore can in principle have

[8] As Browning has pointed out, the effects of these programs on the distribution of income is hard to analyze from published statistics, which refer only to money income. According to his calculations, the distributive effect has been substantial, although it has been accomplished at a relatively high cost because subsidies linked to particular expenditures (such as food and housing) are inherently inefficient in raising real income.

two effects on participating households: it increases their disposable income by the money value of the bonus stamps (those received free of charge), and it reduces the relative price of food. These two effects offset each other. Since the stamps can be used only to buy food, their money value is less than their face value. It appears, in fact, that food stamps are traded at about half their face value.

While these two effects are fundamental in analyzing the impact of food stamps, the problem is complicated by the fact that some participating households would have spent more on food than the face value of their stamp entitlement (the $154 per month just mentioned for four-person households) even if they had received no stamps at all. Such households presumably use the stamps to pay for their accustomed food bill. Their disposable income rises by the full face value of the bonus stamps, but the relative price of food to these households does not fall. (For a detailed analysis see Clarkson.) Their food consumption would rise only by what they spend on food out of the increase in disposable income. This is not to be considered a defect of the program, whose principal economic justification is that it enables poor families to attain an adequate diet. It represents, however, a rather complicated way of raising the disposable income of households who are probably relatively well off to begin with.

In its present form and coverage the food stamp program is too new to permit conclusive evaluation of its effects on the demand for food.[9] The size of the food stamp program, as measured by budget expenditures (U.S. Dep. of the Treasury), was introduced as an explanatory variable in the demand analysis for the United States discussed earlier in this paper, but it was either not statistically significant or significant with the wrong sign.[10] There are as yet no comprehensive cross-section data, similar to the 1965–66 Household Food Consumption Survey, in which food stamps are isolated as a factor influencing food purchases, but such data are expected to be available in 1976. Aggregate data on nutrition do not suggest any marked change in the nutritional status of the population in recent years (USDA 1975); an increase in the availability of vitamins A and C is offset by a decrease in calcium.

The Role of Inventories

In addition to concern about malnutrition, the second justification for a national food policy admitted in this paper was excessive fluctuation in food prices due to inadequate inventories. As figure 3 shows, there has indeed been a considerable fall in inventories since the middle 1960s. In 1974 stocks of both wheat and corn at the end of the crop year (July 1 for wheat, October 1 for corn) were at record lows, yet at the same time foreign demand for our crops was particularly intense. Increased exports had been a major factor in the rise in food prices during the Great Inflation of 1972–74, and they had also depleted our inventories.

The international aspect of inventory policy, in fact, is of crucial importance. For several basic farm products, including those charted in figure 3, the United States is now the world's supplier of last resort, a position attributable to the efficiency of our farmers and merchants and of such marketing institutions as the Chicago Board of Trade. In addition, our agricultural policies have long favored—indeed, sometimes overstimulated—farm exports, to the benefit of farm income and the balance of payments but occasionally at the expense of domestic consumers. The natural desire of farmers for profitable overseas markets has increasingly clashed with consumers' concern over sudden rises in food prices.

It would take great confidence in the efficacy of the political process to argue that it could resolve this conflict better than the free market.[11] Nevertheless, there may be a case for improving the stability of the free market, that is, for reducing the probability of sharp price fluctuations. Because of the large risks involved, the stocks held by private operators may be smaller than is socially optimal, and prices may be correspondingly more volatile. The Commodity Credit Corporation, what-

[9] A recent government study (Reese, Feaster, and Perkins) is largely inconclusive, although it does find that in 1972 the aggregate demand for red meats was 0.85% larger as a result of bonus stamps. Clarkson reports that food stamps did not account for the relative improvement in per capita disposable farm income (p. 81). He also presents estimates of the benefits to participating households.

[10] The latter finding is presumably due to multicollinearity. The recent massive expansion of the program coincided with a rise in the relative price of food and a fall in real disposable income. Future observations may make it possible to disentangle these effects.

[11] Some government intervention is needed, however, in the case of exports to communist countries whose monopsonistic buying practices have at times (especially in 1972) constituted a disruptive abuse of market power. The recent agreement with the Soviet Union promises to be helpful in this respect.

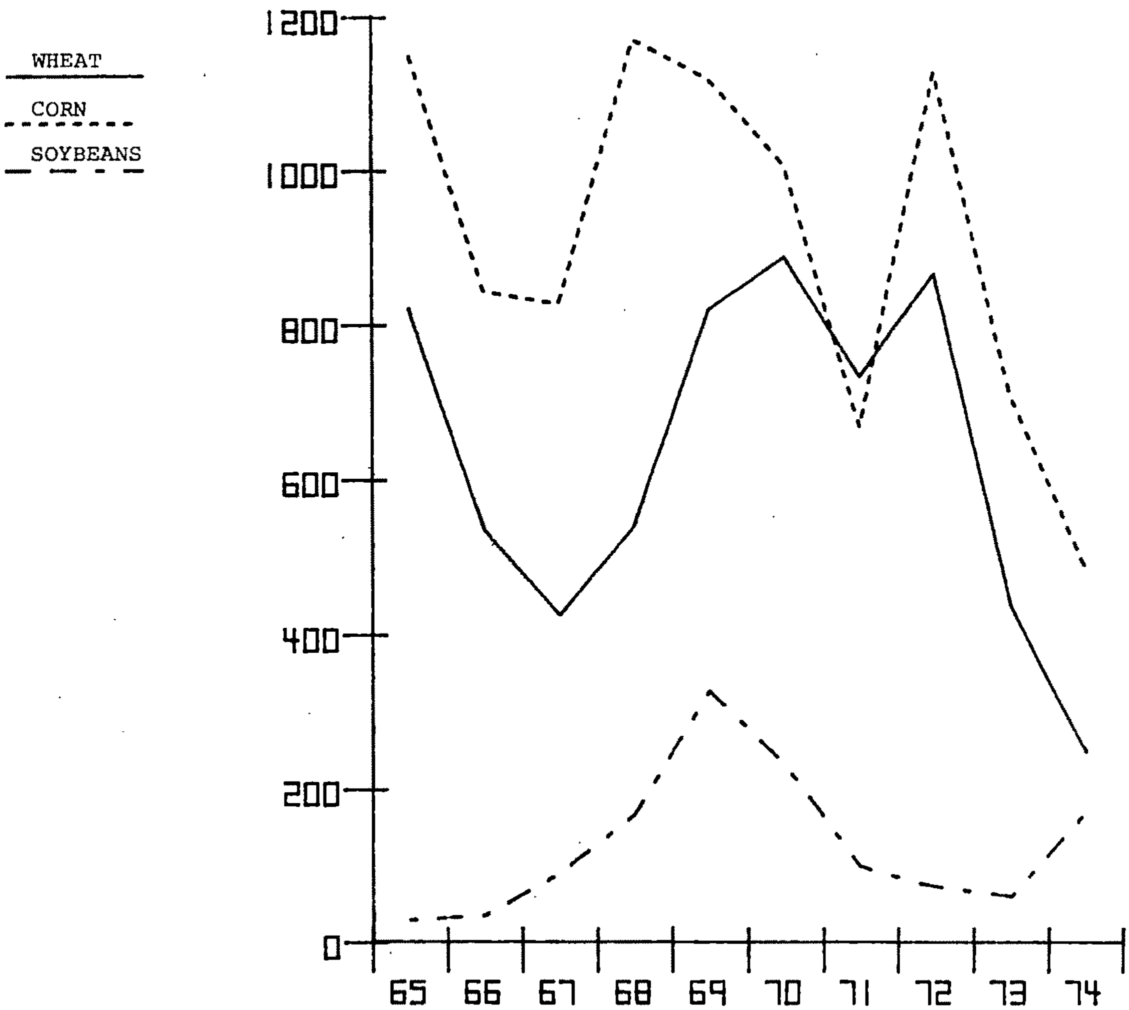

Figure 3. Carryover stocks

ever else it may have done, did help keep prices stable when it carried large inventories, but it no longer does. In any case it is not clear that government stocks are desirable for this purpose, since their acquisition and release may be subject to political pressures. To do the most for price stability, the inventories should probably be partly in the hands of farmers and partly in those of merchants.

If larger stocks are to be held by the private sector, the risks just mentioned have to be reduced. In the case of farm stocks, this could be done by an appropriate support price, set at a level that will prevent disaster but not encourage production. Trade inventories would presumably be hedged in the futures markets, where an official agency could participate as a buyer or seller (according to prescribed rules) to permit an adequate volume of hedging.[12]

Whether this agency should be national or international cannot be fully analyzed here; suffice it to say that price stabilization can—and under ordinary circumstances should—be profitable, at least over a period of years. Improved arrangements for food reserves should therefore not necessarily be viewed as a burden to be shared with other countries. The danger of leaving this task to an international organization is that prices may be fixed at unrealistic, politically determined levels.

Conclusions

If a national food policy is needed, it is not because the food markets are seriously malfunctioning. Thus, there is now evidence of a

[12] See Houthakker (1967). Some of the rules proposed there need revision in light of the discussions of flexible exchange rates in the early 1970s.

significant price elasticity on the demand side. More valid reasons for government intervention are malnutrition, especially of children in low income households, and excessive price fluctuations. It appears that malnutrition in the United States is largely confined to foodstuffs (milk, fruits, and vegetables) whose prices are kept artificially high by marketing orders and import restrictions. There is as yet little evidence that the food stamp program has had much impact on the nutritional status of the population or on the aggregate demand for food, but the program in its present size is still new.

Rather than dream about a comprehensive policy, we should perhaps concentrate on correcting those partial policies that impede the efficient use of food resources by distorting the market mechanism. In addition, measures to relieve specific malnutrition, and to facilitate the holding of adequate inventories by private operators, may be needed.

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Food Policy: Implications for the Food Industry

Gary L. Seevers

This paper addresses the question of food policy from the standpoint of the domestic food industry.[1] My thesis is that the turbulent 1972–75 period has been unique and should not be used as a prototype of future problems. Several of the destabilizing influences during this period should be less significant in the future. Moreover, coming as it did after a long period of relative price stability, it caught both the food industry and the government off guard, and their initial responses often exaggerated the situation.

The food industry has been operating under conditions of greatly increased uncertainty since 1972. One source of additional uncertainty has come from food markets themselves: fluctuations in the supply and demand for food commodities generated short-term price volatility and concurrently contributed to doubts about the longer-term outlook. The second major source of new uncertainty derives from governmental policy: unexpected government interventions have become more frequent, and the absence of a political consensus on food issues leaves the most probable future policy in doubt.

There is an obvious interaction between market instability and government policy. Economic pressures in food markets enabled the government to discontinue obsolete production-control and export-expansion programs that had been widely criticized from an economic standpoint. However, the same economic pressures intensified conflicts between various interest groups and brought forth new government measures that added to uncertainty.

As one would expect, processes of adjustment have been set in motion in the food industry. Firms are altering business practices as the food industry searches for a new equilibrium. A similar search is also underway within the government, as the political system attempts to arrive at a new policy equilibrium. This process is slow and complex because it involves the resolution of conflicts between divergent interest groups and economic philosophies. In particular, conflicts between domestic and international objectives will be difficult to resolve.

The food industry's adjustment depends on some prediction about future government policy, but this depends on many imponderables including market developments. This state of affairs has caught the food industry in an intense national debate about proper food policy. Firms are making decisions with little certainty about the rules under which they will operate.

Market Instability

It is useful to think of the emergence of instability in two stages. The first stage became evident quite abruptly in late 1972, although its causes trace back somewhat further. Tweeten and Plaxico have succinctly summarized this change. The agricultural economy had been operating at about 5% below full capacity for many years. Given that the relevant elasticities for farm products are quite small, this margin was sufficient to provide a condition of abundance and price stability. Farm programs prevented excessive downside price fluctuations, and excess capacity together with ample grain stocks served as an effective cushion against large upside price swings. Then, over a brief period starting in 1972, export demand increased by approximately the amount of the excess capacity.[2] Along with a

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[1] The term "industry" is used broadly to encompass the major segments of the industry—input suppliers, agricultural producers, handlers and processors, and wholesale and retail distributors. Although little differentiation is made among various industry groups in this paper, I believe producers have been the most affected by the instability in commodity markets followed (in order) by processors and handlers, input suppliers, wholesalers and retailers.

[2] The leading cause of the upward shift in export demand is

Table 1. Measures of Destabilizing Influences on Food Commodity Markets in the United States, 1964–67, 1968–71, and 1972–75

Measure	1964–67	1968–71	1972–75
U.S. grain yields[a]			
Corn	5.7	7.2	10.7
Wheat	2.2	6.2	6.2
U.S. economic fluctuations[b]			
Real GNP growth	1.9	1.8	4.1
Consumer price index	0.8	2.0	4.8
Grain trade (ex-USSR)[c]			
World imports	9.0	5.6	10.1
U.S. exports	9.3	8.3	11.4

[a] Average percentage deviation from linear trend of actual yields during 1955–75 crop years; several alternative measures of yield variability gave similar results.
[b] Average deviation from normal percentage increases of 4% and 3%, respectively, (calendar years).
[c] Average percentage deviation from 3-year moving average (fiscal years starting July 1).

strong domestic economic expansion, this brought equilibrium supply and demand into balance at a substantially higher relative price for food commodities in domestic markets.

The second stage, since mid-1973, has involved the instability of commodity markets operating in the absence of considerable excess capacity; greater price volatility is a predictable consequence. However, several extraordinary destabilizing influences compounded the problem during the 1972–75 period. (Table 1 gives comparisons with preceding four-year periods.) Domestically, grain yields deviated more sharply from trends, and the eruption of general economic instability caused greater fluctuations in domestic food demand. World market developments also had more influence on domestic markets. World grain trade and U.S. exports, even excluding USSR purchases, were more variable; the sporadic USSR purchases fostered chronic uncertainty in markets. In addition, certain aspects of price controls and the disruptions from the energy problem both contributed to instability and uncertainty during this period.

To a significant extent, domestic influences have contributed to the new market instability. Prior to 1972, domestic influences were relatively minor; fluctuations in export demand were the primary source of instability. In the future, it seems unlikely that the unique combination of destabilizing influences of the 1972–75 period will be replicated. Export demand is likely to become the primary source of instability again.

Private Sector Response

Market instability has created a general disequilibrium that is causing firms to make numerous adjustments.[3] These adjustments vary considerably from one part of the food industry to another. Although somewhat conjectural, several general directions of adjustment are apparent.

Firms are giving greater attention to collection and analysis of commodity market information, partly because previous relationships are less reliable and partly because outlook information has acquired greater value in decisionmaking. One indication is the new emphasis on the agricultural sector in private macroforecasting models; the desire to improve macroforecasts is one reason, but another is more requests from clients for agricultural forecasts. The acquisition of information on international commodity markets is more essential. For example, several firms now subscribe to weather reports on the USSR to monitor crop developments.

The removal of chronic surpluses has caused firms to shift emphasis from merchandizing their outputs to procurement of inputs. Forward contracting appears to be spreading for commodities that previously were sold primarily on a spot basis. One would expect firms to maintain more inventories to assure their input supplies, although high interest rates may have offset this adjustment. Inventory data are too unreliable to evaluate this possibility.

Volatile commodity prices have been an incentive for firms to increase their use of futures markets, for hedging fixed-price commitments and inventories, and to establish prices for subsequent cash transactions. For instance, the open interest in wheat increased 142% between the 1971 and 1974 crop years, and the proportion held by large, long hedgers

subject to some dispute. The devaluation of the dollar certainly had a pervasive influence, and increased USSR imports have been a specific source of new demand.

[3] The sharp increase in market instability raises many practical and analytical questions. How fast is adjustment occurring? Will it result in over investment? Will it eventually restore a more stable market environment? How does market instability affect the complex institutional relationships within the food industry? What is the impact on optimal firm size, enterprise diversification, vertical coordination, and the distribution of returns to managers with unequal capacity to deal with uncertainty? Will the disequilibrium created by market instability retard or induce technological progress?

increased from 51% to 65% (short hedging increased from 47% to 60%). Similar changes occurred in corn and soybean futures. Livestock futures are less widely used than major crop futures, but their use has also expanded, especially short hedging of cattle. Some cattle feeders have started using futures markets to lock in feeding margins.

Aside from price volatility, higher relative prices for food commodities have provided incentives to expand productive capacity. Accelerated capital formation is occurring, for example, in fertilizer production, transportation and handling of grain, and farm production. This necessary expansion will help avoid supply bottlenecks and increase future price stability.

A case can be made that the market instability of the past three years is greater than would exist if similar conditions were repeated. Under repeated but similar shocks, an economic system will learn to cope with the shocks, and the response will become less destabilizing over time. The sugar crisis of 1974 is a good example. For four decades the sugar program had imposed rigid price stability on domestic markets by isolating them from changes in world markets. Beginning in the early 1970s, world sugar stocks began to diminish because of rising consumption that exceeded production increases. The implications were not perceived promptly by domestic buyers, probably because they had become accustomed to a horizontal supply schedule for raw sugar. The protection and certainty provided to the sugar industry disappeared as world prices strained the sugar program beyond the breaking point. Initially, the sugar industry reacted by trying to build inventories in the face of a shortage. Rumors of large purchases by the USSR and certain oil-exporting countries contributed to panic buying, and sugar prices increased five-fold in a few months. However, two pieces of information became recognized. First, there was not an absolute shortage of sugar in the sense that sugar could not be purchased at any price. Second, it became evident that consumption would decline more than anticipated in response to higher prices. During this learning process, prices overreacted; subsequently, they declined and have become relatively stable. This pattern of overreaction to a reduced supply, sharp price increases, followed by fairly stable prices occurred in markets for many commodities in the past three years. In most cases, uncertainty over governmental response added to the overreaction. The point is that, after a period of overreaction and adjustment, reasonable stability was restored to markets. This behavior pattern warrants additional investigation, but it seems reasonable to expect that under similar circumstances the overreaction would become progressively less severe.

Governmental Response

The turbulence in food commodity markets has contributed to making food policy a major national issue. During the extended period prior to 1972, policy participants and impacts of decisions were much more confined. The foremost consideration of policy was the management of surpluses that were prone to exist at politically tolerable prices. Policy was oriented to commodities produced rather than foods consumed. Policy emphasized the income of producers and specifically the welfare of family farms, which accounted for the bulk of aggregate production. The international dimension of policy was mainly to alleviate domestic surplus problems. Food policy and issues tended to be resolved within the agricultural establishment.

As food policy gained national prominence, new participants became active in the debate. The agenda is no longer the primary province of the agricultural establishment (Paarlberg). Consumer interests have become ubiquitous in food price stabilization issues.[4] They have greater access and influence even though one can question whether they bring useful information to the decisionmaking process. Consumers have long been prone to complain about high food prices, but the sharp increases, particularly in early 1973, transformed a chronic concern into an acute one. Even though the rise in relative food prices occurred over a short period (table 2), it is a good bet that consumers' active involvement

[4] Organized consumerism actually began to appear much earlier, particularly in efforts to restrict the use of food additives under Food and Drug Administration regulations. The 1969 ban on cyclamate (an artificial sweetener) and the 1972 ban of DES (a feed additive) are prominent examples but not the only ones of this form of consumerism. Recent restrictions on pesticide use, air and water pollution controls, along with new health-safety requirements, are the consequence of the "quality of life" consumerism that began in the late 1960s. For many segments of the food industry, the impact of these peripheral aspects of food policy has been as significant on their operations as or more so than the market instability. Because of tensions among interest groups, governmental decisionmaking in these areas has been sporadic and an additional source of uncertainty.

Table 2. Annual Percentage Increases in Food, Nonfood and All Items in the Consumer Price Index Since 1967

	12 Months Ending in December			
	1972[a]	1973	1974	1975
Food	5.2	20.1	12.2	6.5
Nonfood	5.5	5.6	12.2	7.1
All items	5.4	8.8	12.2	7.0

[a] Compared with 1967 annual average.

in food issues will be a permanent consequence. They have played key roles in congressional deliberations on farm legislation since 1972.

Consumers may be the most important new interest group, but several additional groups have intensified their participation: organized labor, supporters of domestic food assistance programs, and the foreign hunger lobby. Participation in the policy debate during the 1960s was dominated by conflict resolution among producer groups and rising influence by agribusiness interests. That debate involved the role of government in managing surpluses; the new debate centers more on the allocation of limited food supplies among competing uses.

Priorities among policy objectives have been turned upside down. The level of farm income was an overriding concern during the 1960s, budget costs were a close second while food prices and international objectives were less prominent. Now, stability of farm income is important, and budget costs of farm programs are insignificant.[5] Food price stabilization and international objectives have much higher priority today and they have frequently come into direct conflict. For example, export-expansion programs that contributed to priority objectives prior to 1972 became inconsistent with the trade-offs after 1972. On balance, export policy has become restrictive rather than expansive compared with market-determined levels.

The resolution of the competing interests and objectives has frequently resulted in a whipsaw effect on major elements of the food industry. The lack of a consensus on policy issues has left the food industry with uncertainty about the stability of policy. This is best illustrated by pressures on grain export policy, a pivotal issue throughout the period.

Even after the costly experience with soybean export controls in mid-1973, there was major pressure to place controls on wheat through the following winter. By the spring of 1974, the prospect of bumper crops and falling grain prices eliminated consideration of controls. However, bad weather steadily dimmed crop prospects through the summer, prices rose, and export restraints were again on the policy agenda. A system of day-to-day monitoring and approval of large sales was launched, sales to the USSR were restricted to minimal amounts, and consultations with other countries led to "diplomatic" export restraints. The monitoring system was in place only a few months until grain prices fell rather sharply again. Pressures built to abandon any form of export restraint, which was done in early 1975. Only a few months later, however, new USSR purchases triggered steps to restrict exports once more. In a twelve-month span, the government intervened to restrain exports, acted to discontinue all restraints, and then intervened again.

The ability to predict government actions has become an important decision variable in the food industry. Fortunately, government policy is capable of adjusting to new circumstances, and some signs of consensus are emerging. Judging by revealed preference, the nation's food policy represents a sharp departure from the past.

There is a policy of large domestic food subsidies. Low income families receive several billion dollars annually through the food stamp program. Benefits are indexed to retail grocery prices, and participation varies with swings in economic activity. When combined with other federal food assistance programs, federal outlays are equal to 4% of retail grocery expenditures.

The commitment to food aid has been reaffirmed. P. L. 480 grain shipments are expanding modestly, and the U.S. share of world food aid is returning to past levels even without domestic surpluses. Perhaps more important, the distribution is being redirected to meet humanitarian objectives through congressionally-initiated provisions that set minimum percentage requirements for humanitarian aid, in contrast to "political" food aid. Beginning in 1969, as foreign-aid funding diminished, food aid began to be used in more

[5] Domestic food programs have become a big ticket budget item, partly because of higher relative food prices. In fiscal year 1970, budget outlays on farm income-support programs were $4 billion and domestic food programs were $1.6 billion; in fiscal year 1975, farm programs were $0.6 billion and food programs were nearly $7 billion. P. L. 480 outlays were comparable in both periods.

overtly political ways. It was first used in Indochina as a source of funding as other forms of foreign aid became tighter. Once the food-aid tool was discovered, it became widely employed for political purposes until dissatisfaction with this use of food caused congressional restrictions. In other areas of foreign food policy, it is evident from numerous policy statements that the administration attaches a great significance to food in the conduct of foreign policy. The combination of specific proposals and actions to deal with world food problems constitutes a rather ambitious program.

Periodic interventions to restrict exports or to allow more imports (mainly of dairy products) have had very disruptive market effects. The limitations of using this approach to achieve domestic objectives are many. Such steps are often contrary to a liberal trade policy; actions tend to be disruptive not only to domestic markets but also markets abroad. Even if only domestic objectives are considered, the lags between problem recognition, making a decision to act, and the impact of the action are sufficiently long that the effect on domestic markets is often untimely. As the problems with ad hoc actions to influence trade flows are recognized, the propensity to use trade measures for short-term domestic purposes has diminished. The recent agreement with the USSR should help remove one persistent pressure for periodic export controls.

The most constructive way to provide more stability in commodity markets would be to liberalize agricultural trade on a multilateral basis. Johnson has discussed the implications of rigid internal price stabilization policies in some countries on price instability in other countries. Signals of worldwide surplus and scarcity simply are not permitted to be transmitted to a large proportion of the world's producers and consumers. Since the United States accounts for much of the open markets, our food industry must adjust to global fluctuations to a far greater extent than would otherwise be the case. Unlike the pre-1972 period, when the average level of protection was the dominant problem, insulation from changes in world markets has become the dominant problem under the new circumstances. The current round of trade negotiations is an opportunity to focus on both problems, although progress will be slow at best.[6]

Unresolved Issues

Food policy may be taking shape in certain areas, but it remains highly unresolved in other areas that have important implications for the food industry. One area is grain price supports. How high should they be? Should they take the form of direct payments to producers, or floors under market prices? According to provisions in the Agricultural and Consumer Protection Act of 1973, which link price supports to the parity index, target prices for the 1976 crops will increase about 11%. However, the supports still will be sufficiently low, so that for all practical purposes the food industry will continue to operate without government price supports. Based on past experience, it is clear that, if price supports were to be set high enough, stability could be restored quite easily, but this would reactivate problems similar to those of past farm programs. The costs of attaining stability through higher price supports almost certainly would be quite high. This does not preclude modest increases. Useful guidelines have been suggested by Robinson, who also recommended that the implicit grain reserve system in current legislation could be improved by raising the spread between acquisition and resale prices. This approach would continue the market-oriented policies that have evolved over the past twelve years.

A second possibility is an explicit system of government grain reserves designed to stabilize prices, rather than the current system, which is only a back-up to price supports. The case for a purposeful reserves policy seems quite convincing. Conceptually, a reserves mechanism could maintain market prices within a prescribed band and provide at least three potential benefits. (*a*) Greater stability will reduce income transfers between producers and consumers and presumably the anxiety that goes with such transfers. Whether grain producers or users would benefit is unclear in the theoretical world of consumer and producer surplus (Turnovsky). (*b*) Steep rises in food prices can have adverse macroeconomic externalities that are not necessarily offset when prices decline (Okun). (*c*) Reducing price uncertainty will lead to more efficient allocation of resources, particularly at

[6] The recent bilateral grain agreements with two state-trading nations (USSR and Poland) will be contrary to trade liberalization objectives if they proliferate. Being bilateral, they are inconsistent with the most-favored-nation principle. They could also introduce new rigidity into trade flows. For example, these two agreements restrict discretionary purchases to a narrow range of only 8 million to 11 million tons per year.

the producer level but also elsewhere in the food industry.

In order to realize these benefits, the system must be designed so that it actually operates to stabilize prices. Reserves should be insulated from political pressures that would cause untimely release and acquisition. This would be a major advantage of a purely automatic system based upon decision rules. Recent analytical work on appropriate rules is helpful in this regard but, in my judgment, is not advanced to the point of being workable. A purely discretionary approach, in addition to being vulnerable to political pressures, would require improvements in worldwide crop intelligence in order to successfully stabilize prices within a reasonably narrow band around a long-run equilibrium price.

In weighing the costs against the benefits, it is important to consider adverse ramifications beyond easily measured operating costs. The system should be designed to minimize the substitution of government for private stocks in the United States. It should also take account of similar disincentives abroad, including neglect of agricultural investment in developing countries.

Assuming the United States is unwilling to resume its pre-1972 practice of holding reserves de facto for the rest of the world, a unilateral system would have to include one of two features. It would have to either limit access to reserves (e.g., only for food aid), which would reduce its stabilizing benefits, or incorporate a commitment to manage total export supplies in order to keep fluctuations in domestic prices smaller than export prices. The latter approach could be achieved with quantitative restrictions or, more efficiently, with export taxes and subsidies. It even has been argued that the United States should manage grain export supplies in order to exploit its short-run monopoly position in certain markets, but this would be inconsistent with a liberal trade policy and raise other objections.

Many of these difficulties could be overcome with a multilateral system that would force other countries to share the costs of reserves in relation to the benefits they receive. A proposal of this type by the United States is currently under consideration. However, other countries have been reluctant to confine discussions only to reserves since they want to incorporate other variables along the lines of a conventional commodity agreement. The design of a reserves system consistent with other aspects of policy is more complex than the idea seems on the surface. In particular, proposals to simply attach a system onto present farm programs seem to give too little regard to the international ramifications of domestic grain reserves.

A third unresolved issue has to do with data adequacy and statistical policy in both the food industry and the government. Increasingly, the private sector is required and expected to produce data that it may not, in fact, have available even to itself. Serious deficiencies have been revealed in the information of firms and especially of industry-wide data. Public demands for all kinds of information are sure to rise in the future, and the food industry's capacity to produce and interpret it must expand. This raises questions about how publicly accountable private firms should be required to be. Numerous deficiencies have also appeared in the government's statistical programs. Improvements are being made or are under study, but much remains to be done. Improvements in food policymaking will be contingent on better information systems to a greater extent than is often appreciated. The government also needs to give higher priority to sound procedures for making and announcing food-policy decisions. Unnecessary market disorder can arise from careless internal procedures, announcement of decisions, and release of market-sensitive information. The tradition of the U.S. Department of Agriculture in this area needs to be encouraged and extended to other points where food policy questions are addressed.

Conclusion

The food industry has adapted to the exceptional period of 1972–75 in a variety of ways, including investments to expand productive capacity in response to expanded demand. Government policy has likewise responded to the switch from relative surplus to relative scarcity, although more slowly. New participants have entered the policy debate, priorities have changed, and different policy measures have replaced those that became obsolete. The search for a national food policy has yielded tentative consensus in a few areas. It is far from complete, however, particularly regarding the stabilization of grain markets.

From the standpoint of private planning in the food industry, knowing what food policy

will be may be as important as its content. Food policy needs to have durability and consistency. If a particular policy's expected life is short, efficient planning within the food industry will be inhibited. Uncertainty over policy or frequent changes affects production and investment decisions just as market instability does.

One major need is to be able to upgrade the quality of decisions that are made regarding food policy. This will require improvements in information systems and diligence in handling market-sensitive information. But it also will require that policy not try to become overly ambitious in its scope and content. It will be wise to concentrate on the strategic issues, such as the merits and methods of grain price stabilization, rather than to overload the food policy agenda.

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Discussion

Daryll E. Ray

Seevers' paper focuses primarily on the sources of recent instabilities in the food markets and initial private and government reactions to those instabilities. His thesis that the turbulent 1972–75 period should not be used as a prototype of future food industry problems is of interest, but of more concern is the market environment that can be expected and policy propositions consistent with the future environment.

Seevers seems to imply that since future turbulence in food markets is unlikely to be as severe as in the last three years, there is no urgency in reevaluating our food and agriculture policy. While general policy options are mentioned, no recommendations are made, and the status quo seems to win out by default. Rather than critique Seevers' chronicle of past food industry tribulations and government errors, my discussion centers more on policy reformation.

Orientation of Food Policy

As suggested by the National Planning Association, public policy for food and agriculture must be sufficiently flexible to handle a wide range of future market eventualities. To begin with, the foresight to predict accurately the relative growth rates in supply and demand of U.S. agricultural products in the years ahead is not available. In the shorter term, continued price fluctuations due to the low levels of U.S. and world grain stocks, year-to-year weather variability, and the extreme inelasticity of grain demand is expected. Hence, our food policy must be capable of handling year-to-year shortages and surpluses about a long-term trend of either falling or rising real prices for food.

In the following discussion, it is assumed that the objectives of a food policy are (*a*) to assure domestic consumers of ample food supplies, (*b*) to provide a degree of income protection to farmers from plummeting prices due to overproduction, (*c*) to modulate extreme price fluctuations and the attendant shocks to consumers and producers—especially livestock producers, (*d*) to encourage expansion of dependable export markets, and (*e*) to provide food assistance to those in the United States who cannot afford an adequate diet and to assist in international famine relief and agricultural development.

The challenge is to develop a policy framework appropriate for achieving the objectives. The Agriculture and Consumer Protection Act of 1973 protects neither farmers nor consumers from market contingencies (Ray and Tweeten). Governmental actions outside the Act have been disjoint and counterproductive. In the remaining space, a suggested policy framework is briefly outlined.

Price Support and Stabilization

As Seevers points out, price supports are set so low in existing legislation that for all practical purposes the food industry is operating without effective supports. In November 1975, target prices were 44% of parity for wheat and corn and loan rates were 29% of parity for wheat and 35% of parity for corn. With the increases in agricultural productivity over the years, full parity prices are obsolete, but parity percentages as low as implied by current target prices and loan rates would spell disaster for production agriculture. To effect the efficient short-term use of resources and longer-term investments in agriculture, farmers must have some price and income assurance. Target prices are a convenient means for supporting income especially if price declines are only periodic. To provide income protection, target prices must be set at reasonable levels. Due to the large input price increases in 1973 and 1974 and gyrations in yields, the target price levels specified in the 1973 Act need to be modified (Ray). Target prices for

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1976 could be specified at levels that reflect a large share, say, 80%, of production costs on efficient-sized commercial farms, including a cash-rent land charge. Hence, only part of land costs would be included in 1976 price levels. To avoid validating further escalation of land prices, annual adjustments after 1976 could be based on changes in nonland-operating costs of producing individual crops. Individual farm acreage allotment levels should be recalculated to reflect the crop acreage mix on the farm during 1974–75.

Production control provisions should remain a part of the policy framework. But production control should only be used to cope with chronic excess supplies. Policy administrators should not be allowed to offer voluntary set-aside until reserve (nonpipeline) stocks exceed target levels of 30 million tons of feed grains and 400 million bushels of wheat. When needed, set-aside levels should be calculated so market prices would be near but not exceed target prices with expected yields and demands. Target prices would pick up any price slack should yields be higher and exports lower than expected.

Although income protection must be upgraded, the first priority in food policy must be to implement a purposeful reserve stock management program to even out year-to-year supplies and to reduce short-term price variability. Unlike the 1950s and 1960s, its central purpose would not be to support prices and farm incomes. Target prices and set-aside would be used for that. Rather, the reserve mechanism would be used to help modulate extreme price fluctuations.

The acquisition and release prices for altering stock levels do not need to be fixed but could slide as stock levels change. Loan rates and release prices should approximate the marginal value society attaches to incremented changes in stock levels. In times of zero or low contingency reserves, the acquisition price should be set sufficiently high to reflect the value of accumulating stocks to help combat future sharp increases in prices. Loan rates might even exceed target prices under extremely low stock conditions. As the levels of stocks increase, the need or marginal value of more reserves declines, and so could the acquisition price or loan rate. Under such a plan, loan rates would eventually decline to below the cost of producing the commodity.

Market prices at which stocks are released could also be based on value of the stocks to society. When stock levels are low, stocks would only be released in times of very high prices. The foregone benefit or protective potential of releasing a unit of stock declines as the stock levels increase. Hence, there would be an inverse relationship between the level of stock and the release price. Sharples and Slaughter have advocated using the marginal value concept as a decision criteria and are working on making the concept operational.

The following stock levels, associated loan rates, and release prices illustrate approximately how the decision criteria would operate. Announced loan rates could be 110% of target prices when contingency reserve stocks (exclusive of pipeline or working stocks) were 0 to 15 million tons of feed grains and 0 to 150 million bushels of wheat. With reserves between 15 and 20 million tons of feed grains and 150 to 250 million bushels of wheat, loan rates might be 80% of target prices. Loan rates could be 70% of target prices with reserves between 20 and 35 million tons of feed grains and 250 and 400 million bushels of wheat. After feed grain and wheat reserves, exclusive of pipeline and working stocks, have reached 35 million tons and 400 million bushels, respectively, loan rates might fall off to less than one-half of the target prices or be completely inoperable. The sliding loan rates would tend to encourage further stock accumulations only in times when stocks are inadequate.

To illustrate stock release criteria, stocks might only be released when market prices exceeded 150% of target prices if feed grain stocks (exclusive of working stocks) were 0 to 15 million tons and wheat stocks were 0 to 150 million bushels. The minimum release price might be 135% of target price if reserves are between 15 and 20 million tons of feed grains and 150 and 250 million bushels of wheat. With feed grains and wheat reserve levels between 20 and 35 million tons and 250 and 400 million bushels, respectively, the minimum release prices might be 120% of target prices, and with higher stock levels the minimum release prices might be 110% of target prices. Under no condition would stock sales be allowed to depress prices below target prices. Also, there would be no government intervention in the markets as long as market prices remained between loan rates and stock release prices. The decision rules must be known by all involved—grain and livestock producers, consumers, grain traders, and importers—and must be followed explicitly by the government.

The stocks do not have to be in the physical possession of the government but could remain at the farm level (Tweeten). The government could pay farmers to store the commodities put under loan. Farmers would be directed by the government to place grain on the market when market prices reach release levels. In addition to the storage payment of perhaps 20¢ per bushel per year, farmers, not the government, would realize the price increment between the loan rate on this grain and higher release price (less interest charges). The memory of low prices associated with huge government stocks in the 1950s and 1960s is too vivid to expect farmers to support a grain reserve without inducements.

Food Shortage Syndrome

There is sufficient concern that the demand for agricultural products will press ever harder on supply so that efforts to expand the production potential of agriculture should be considered. Federal expenditures for agricultural research here and abroad could be expanded. Consumers should be made more aware that they, not farmers, benefit from the generation and adoption of improved agricultural technologies. Cost-sharing programs to upgrade, reclaim, and conserve agricultural lands could be revitalized and perhaps even undergo a wholesale expansion.

Our primary responsibility to less developed countries in the food area is to help them develop a sound and productive agriculture of their own. Considerably more funds and technical assistance must be provided to help stem the growing gap between agricultural production and food needs in less developed countries.

The primary objective of foreign food aid should be to relieve hardships created by serious production shortfalls as a result of natural disasters. Ongoing food-aid shipments should be allowed only as part of a comprehensive plan to upgrade the productive capacity of the recipient country.

Domestic food aid has become an important part of our food policy and will continue to be in the future. Our commitment must be to better focus our domestic food assistance programs on those that truly cannot afford to purchase an adequate diet in the market place. Taxpayers should not be expected to buy food for those who could otherwise afford it, and eligibility rules for the food stamp and other programs should be deliberalized, as appropriate, so that they do not.

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Editor's Note: Howard W. Hjort, Schnittker Associates, Washington, was a discussant for this session, but he did not provide a manuscript for publication.

Risk Management in Commodity and Financial Markets

Roger W. Gray

Having been asked to focus upon the problems outside primary agricultural production, and with the additional advantage of our early look at the Barry-Fraser paper, I have chosen to emphasize certain institutional factors in my approach. Recent events have highlighted the transition from institutionalized governmental risk bearing in the commodity sector back to the marketplace, as well as numerous problems and adaptions associated with the transition, including the emergence of a strong international oil cartel, proposals to counter this with other cartels, and a renewed interest in food reserves, as well as international commodity agreements. Concomitant with unsettled commodity prices have been massive disintermediation in the mortgage money market and a serious shrinkage in the availability of private equity capital. Mention of the collapse of real estate investment trusts and of the financial plight of New York City serves only to lengthen the list of horrors from which I must attempt to shrink in some orderly fashion. I shall retreat mainly to the confines of commodity price problems and the organized futures markets to see what has been done or could be done in that area, but I shall also venture a suggestion or two outside the commodity area.

The Role of Government

It is worth remembering that the role of government in commodity price determination had affected not only primary producers but merchants and processors and even consumers as well and had affected not only agricultural products but silver, gold, petroleum, etc. Processors in a number of industries had grown accustomed to reliance upon stable raw materials prices under government programs and had given little or no thought to hedging strategies in futures. As recently as 1970, some major cotton mills made no use of futures and had no expertise in the area. Prior to March 1967, silver users had been presented with pegged prices for many years, as of course had gold users until last year. Domestic beet sugar processors, with the 1963 exception, had dealt with essentially stable prices until the Sugar Act expired last year. The price support programs for grains had a similar effect, and the export subsidy that was maintained even in the face of massive Soviet buying in 1972 enabled grain firms to remain uncovered on sales and thereby delayed the reflection of this demand in the marketplace. Even without the Agricultural Act of 1970, which intended a transition to market prices, the transition would have been wrought by forces that wrenched prices into a free market orbit, anyway.

Meanwhile, the 1960s had seen the development of futures markets in the livestock area—one major agricultural segment that had not been subject to governmental stabilization programs. Thus, when the burden of risk bearing was transferred back to the markets in very recent years, there was a somewhat mixed readiness to take it up. Some exchanges, e.g., cotton, had become quite moribund; others, e.g., grains and livestock, had begun to flourish. Acquired hedging skills were present in some industries and not in others; some bankers were conversant with hedging while others were not; and probably no one anticipated the unprecedented range over which prices would move.

Market Response

In general, the established futures markets absorbed the vastly increased hedging load of

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1973 quite smoothly. Open interest in major grain and soybean futures rose to record levels, whereas cotton futures attracted high but not record levels of hedging. An interesting aspect of the composition of the open interest was the strong rise in long hedging. In wheat, cotton, and the soybean complex, reported long hedging exceeded reported short hedging for the year, whereas in corn futures long hedging averaged nearly as high as short hedging. Considering the unprecedented high hedging levels relative to speculation, the dramatic increase in long hedging reflects the extent to which the price rise rested upon real demand in the form of actual bookings. In the context of price risk, it was not so much shifted from hedger to speculator as from seller to buyer. Export contracts in particular undoubtedly accounted for much of the long hedging (although data are not available to show this), so much of the price risk was transferred overseas. Not only were speculators less involved than usual (in their proportion of aggregate futures holdings) and atypically more committed on the short than the long side in these commodities, but indications were that speculation neither caused nor benefitted from the major price rise. The comptroller general in a report to the Congress concluded from an examination of the trading of the fifty-five largest speculators and twenty-six largest hedgers in soybeans that neither group exerted significant buying pressure during a critical period of rapid price increase (U.S. General Accounting Office, p. 72).

Other major futures contracts attracted significant increases in trading in 1973, including live cattle, live hogs, sugar, cocoa, and copper, none of which, however, are export commodities. In perspective it appears that recent price uncertainty had led to a substantial increase in the demand for hedge protection, which had been accommodated at realistic price levels and to a significant degree between vertical segments within industries.

Some Problems

The foregoing brief assessment should not be taken to imply that the transition from governmental to private risk bearing during a period of unprecedented price change was accomplished without problems, nor that it is irreversible. A host of problems occurred, some of which still persist. Selected illustrations of these problems will reveal the need for and may suggest the nature of some remedies.

Consider first the case of a firm that did not hedge for lack of experience or even lack of any prior need for hedging. One large institutional feeding firm that contracts with schools and other institutions had enjoyed phenomenal growth for a number of years, then suffered catastrophic losses in 1973. The firm had never hedged in futures, and by virtue of a combination of years of stable food prices, skillful menu adjustments, and the ability to contract with suppliers had really not needed futures hedging. All three of these safeguards deserted the firm in 1973, and only during the post mortem did it begin to consider futures hedging. The remedy in this case is education, both in the general sense that management needs to understand futures markets and hedging and in the particular sense that such a firm needs to develop either internal competence or to contract with a firm that provides competence in operating a hedging program.

Another illustration concerns a cotton merchant who contracted with hundreds of farmers at high current prices and could not fulfill the contracts at harvest time after prices had fallen because he had not hedged. This appears to have been more a case of deliberate speculation than lack of hedging experience. In some respects, this resembles the sale of naked options and may require some regulatory oversight.

There have also been exposures against which no hedge was available for one reason or another. Selling livestock futures that would only lock in losses was scarcely an attractive alternative to speculation, even though the hedge was literally feasible. Another problem confronted the processor of specialty crops, such as canning vegetables, produced in competition with hedgeable crops. Contracting for the land at high prices created exposure for the processor, but failure to offer such contracts risked loss of supplies to competing crops. There may have been economic "cross-hedges" available to such processors or to barley malsters or to bakers, but the law did not regard these as bona fide hedging. Institutional adaptations may remedy such problems in time. For example, at least some banks now invoke the rule that acquisitions of feeder cattle will be financed only on a fully hedged basis, i.e., sales of cattle futures and purchases of major feed ingredient fu-

tures. Consideration is already being given to amending the legal definition of hedging to accord more closely with economic realities, the irony having been perceived in a situation that places no legal restrictions upon unhedged exposures but restricts the hedging of exposures.

Great financial risks were also imposed through official neglect of the sanctity of contracts. The embargo upon exports in the soybean complex in mid-1973, however seemingly warranted as a thumb in the dike against rising food costs, had a devastating impact upon holders of contracts to buy. The value of the long open interest in futures in the soybean complex declined by $400 million in seven days, and 50% of the outstanding export contracts were canceled. Apart from its failure to indemnify victims of such action, the U.S. government undermined confidence in its good faith in international commercial relations in such a precipitate edict. Overseas buyers subsequently abrogated some contracts to purchase cotton and grain from U.S. firms, thereby exposing the other side of the coin.

A little recognized aspect of the history of organized futures markets is the extent to which they have evolved as a solution to the "soft contract" problem. It is commonplace for private treaty forward contracts to prove to be either needless or useless. If the price does not change, the forward contract was not needed. If the price does change, the loser reneges and the contract proves useless. The "innovation" of the futures market had really nothing to do with "futurity," which had long since been embodied in the trading of all commodities, but rather with the establishment of a clearing house to keep all contracts "marked to the market" on a daily basis. Thus, the reason why futures contracts are not abrogated owes not so much to the integrity of the contracting parties but owes instead to the fact that there is no incentive to renege—the loser having already paid in his losses has no better alternative than the contract he holds. I point this out not for the sake of recording little-known facts but because it seems to me that international transactions may need to move toward a similar system. It does not matter if Thailand decides not to take delivery on a cotton futures contract that it entered into at higher prices, since it will already have paid the difference between yesterday's and today's prices.

The soybean embargo of 1973 and the 1975 embargo on grain sales to the USSR and Poland pose more fundamental threats. Futures markets can accommodate risk management only if the rules of the game are known and adhered to. The caprice of Henry Kissinger is not one of those risks the marketplace can long absorb, it being quite enough to cope with acts of God. There have been some signs, as in private trade support of grain reserves or buffer stocks, that the trade may prefer a situation in which the government assumes all the risk to one in which the government creates all the risk.

The Commodity Futures Trading Commission

Congressional hearings convened to investigate the performance of futures markets in the aftermath of the Soviet grain purchases, heard several allegations of malperformance in early sessions, but ultimately turned to the more constructive business of regulatory reform. The law passed in 1974 created an independent regulatory commission with considerably expanded and clarified authority compared to the predecessor agency in the Department of Agriculture. By including nonagricultural futures markets under its jurisdiction and by removing the authority from the Agricultural Department, Congress recognized among other things the incipient tendency for futures trading in financial instruments to be organized. At the same time that the law protects the existing jurisdiction of the Securities Exchange Commission and other agencies, it vouchsafes to the Futures Commission supervision of all futures trading in commodities and all other items and interests. Already, by having extended its authority to include futures contracts in foreign currencies, the Congress has nullified its own use of the word "commodity" in the title of the act. Other "items and interests" than commodities clearly meant just that.

Among the problems to which the Congress devoted considerable attention and the CFTC was directed to study are the definition of hedging, the terms of futures delivery with special reference to multiple delivery points, option trading, leverage contracts and other trading instruments, and participation in U.S. markets by foreign nationals or governments. Whether Congress in its perception of the priorities has been infallible is not so impor-

tant as its perception that the institution of futures trading is an important and growing one that needs more attention, better public understanding, and more enlightened regulation than it has received heretofore. That some agricultural economists writing in 1975 could have referred to the futures markets as a "nostrum" reflects all too clearly the need for better understanding. If improved coordination of economic activity and improved capacity for individual firms and industry segments to adapt to changing conditions are to be found, it will require increasing reliance upon and understanding of the opportunities afforded by organized futures trading.

The "Mortgage" Futures Market

The initial extension of the futures concept to "other items and interests" under the new law was the approval of a futures contract reflecting the prices of Government National Mortgage Association securities at the Chicago Board of Trade. This market had its genesis in factors that have given rise to futures trading in earlier circumstances, namely, (*a*) a perceived hedging need, (*b*) an active secondary market, and (*c*) problems arising from parties "walking away" from forward contractual obligations. The most conspicuous hedging need was that of the mortgage banker, whose modus operandi is analogous to that of a grain merchant in that both originate products that they intend to sell in a short time and which are meanwhile inventoried. The difference has been that the grain merchant originated products against sales of futures contracts, whereas the mortgage banker acquired unsold inventory. Certain government agencies had made available standby commitments for firm or optional delivery at fixed prices, and a dealer's market had emerged in GNMA securities issued against government acquisitions of mortgages.

This dealer's market had developed to the point where secondary (resale) volume exceeded the primary volume, and had devised various techniques for pricing the securities ahead. Essentially, these techniques were bringing the mortgage market and the capital market closer together. The intent of the Board of Trade was essentially to organize and extend the activity in this dealers' market under a standardized contract and rules. At the origination, the mortgage banker who entered into a "take-out" commitment with builders had to assume either the risk of changing rates or, if the rates were fixed in advance, the risk that the builder would walk away from the commitment. The hope is that, as through other futures markets, the "soft contract" problem can be eventually solved.

Remaining Legal and Jurisdictional Problems

The pending application before the CFTC to trade futures in short term treasury bills is being opposed by the SEC, as was the GNMA futures contract. This reflects a problem of long standing and also reflects the need for clarification of some basic definitions. Almost a decade ago, the Chicago Board of Trade sought SEC approval to open futures trading in common stocks, which was declined on the ground that it was a transparent effort to provide leverage in such trading contrary to Section 7a of the Securities Exchange Act, which was designed to control the extension of credit for stock transactions. In light of the fact that SEC had closed its eyes to the put and call options trading that had long existed for common stocks, the Board of Trade chose to seek approval to organize that trading instead of pursuing the application to trade futures. In consequence, a major new market emerged around a trading vehicle that is more cumbersome and less desirable than futures trading. Worse yet, the misapprehension that the leverage provided in futures trading somehow equates with the extension of credit has been left unchallenged. Other misconceptions were to follow. First, the firms that wrote naked commodity options created a problem that both state securities commissioners and the SEC attempted to solve by designating such contracts "securities," which they clearly are not in the history of case law nor in the common definition of a security. Subsequently, officials of the Federal Home Loan Mortgage Corporation sought an interpretation by the SEC that futures contracts for mortgages or mortgage-backed securities would be exempt from the act, only to reach the bizarre interpretation that while a GNMA security would be exempt, a futures contract calling for delivery of that security would not be. In other words, a security is not a security, but a nonsecurity is a security!

It is not clear on what grounds other than Parkinsonian ones the SEC presumed to object to futures trading in GNMA securities

after the CFTC had approved it, nor what the SEC objection may be to futures trading in treasury bills. It is clear enough that the congressional intent was to assign the responsibility for futures regulation to the futures commission, but it seems that the SEC may still have to learn the unequivocal fact that a futures contract is not a security. Fortunately, a strong agency now exists to help drive home the fact.

The new legislation and the commission that it created have several implications for risk management. Existing futures markets should be better understood, better regulated, and more widely used if the congressional intent is fulfilled. Problems of long standing, such as the Chicago delivery problem, are likely to be resolved under the new legislation. New futures markets, whether for commodities or financial instruments, will receive support wherever the commission finds evidence of economic need or potential usefulness. In short, the transfer of risk absorption from government to private hands, however partial or tentative it may be, is given a helping hand in the form of a government agency designed to strengthen the private institution most directly involved—the organized futures markets.

Some Remaining Problems

The risk-absorbing markets having enjoyed record levels of activity and having received a firmer official sanction than ever before does not mean that problems both internal and external to their operations will not persist. Internally, for example, we may well wonder how much waste is involved in a porkbelly futures market that looks more like speculators taking in one another's laundry than a true hedging market. How much more useful an allocation of venture capital would be achieved if a large fraction of porkbelly speculation could be diverted to hedging markets that attract too little speculation (of which there are several)? Or how large would the silver futures markets be if all the "tax spreading" were removed from their business, and how well warranted is such tax spreading? If tax advantage is justified to elicit venture capital per se, would it not be better to do this directly? Or to take another example, is there any danger that the fledgling mortgage futures market will only reveal how sheltered the specialized savings and loan institutions have been and perhaps will underscore the social desire for separating mortgage rates from the general capital market. Questions are also raised regarding the capacity of existing futures markets to take on additional contracts, especially in financial areas that are much larger than the traditional commodity areas, but the exchanges can probably devise methods whereby adequate market-making capability is assured (as with the Chicago Board of Trade's issuance of permits to trade GNMA futures).

External problems loom larger on the horizon than any of the above. Renewed efforts to organize commodity agreements or to organize cartels threaten a reversal of the recent transition of risk bearing to the private sector. Despite the overall dismal record of such agreements and the difficulties confronting cartel arrangements for most commodities, high energy costs reflecting the success of one cartel have evoked clamor from commodity-exporting nations to institute controls.

The food-price problem is perceived in many quarters as separable from other risky situations, especially since the entry of the Soviets into the world food picture. Some sort of official grain reserves scheme appears likely to emerge in consequence. While there is little doubt that governments can absorb risk in this area, the questions—at what costs in treasury outlays by which governments, at what costs in misallocation of resources in general—remain. From the standpoint of risk management in the commodity industries, the chief concern is that the terms of governmental participation be known in advance and be focused upon extremes of surplus or shortage to enable normal commercial risk management in the marketplace.

Structural Implications

Specialization in risk management, or developing optimal hedging programs, implies a large enough entity to justify expenditures for that purpose, and may thus appear to augur increasing concentration. Many commodity merchandising and processing firms, however, enjoy little scope for competition in technical efficiency and have long engaged in risk-management competition. The flour mills and soybean crushing firms have been sorted out, not so much according to manufacturing efficiency, which is reasonably uniform, but

more according to risk-management skills. There are also a growing number of firms specializing in developing and conducting hedging programs jointly with firms that are too small to afford their own research and risk-management capability.

By and large, of course, the futures markets have invigorated competition. Entry barriers are low, trading is conducted openly without serious possibilities of price discrimination, and the fragmented markets that antedated futures (and might otherwise exist) are brought together. At the same time, a larger individual trading. The many small potato dealers who leverage and protection afforded in futures trading. The many small potato dealrs who long opposed the futures market were rationally self-interested individuals who did not like seeing their isolated monopolies encroached upon. Similarly, the GNMA dealers at first opposed a futures market but, being more sophisticated, were also quicker to observe that they might make more money at a lower bid-asked spread on larger volume.

The most concentrated of any major futures market, among a number reported on as of 31 October 1975 by the CFTC, was corn futures at Chicago, where four traders held 48.5% of a very large long open interest. One can guess that this might be Cargill, Continental Grain, CPC, and Bunge or Cook, but apart from conjecture it is nevertheless a concentration ratio that is not high by other industry standards and a position that was established openly and competitively. Futures hedging also affords an alternative to vertical integration, although the two are not mutually inconsistent.

A final point that will not be developed at length here but that needs to be suggested in the context of risk management is that the major commodity firms that rely upon futures hedging are not so much risk averters, as the stereotype would have it, as they are risk selectors. They choose to earn their profits by skillful risk taking in "basis" relationships—relationships between cash and futures prices. Their rare exposure to flat price changes does not characterize them as risk averters—they simply take their risks in a different business. Their risks have been greater and their rewards higher since 1972 because they are skillful in risk management. Glancing at the other side of the coin, the professional futures speculator is typically a skillful risk manager as well, who scarcely fits the stereotype of risk lover. Risk management, as the organizers of this program recognized, is more apt terminology than risk aversion versus risk loving.

Reference

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Risk Management in Primary Agricultural Production: Methods, Distribution, Rewards, and Structural Implications

Peter J. Barry and Donald R. Fraser

Price variability of agricultural products has increased greatly in the early 1970s owing to modified government programs for many U.S. commodities, reduced crop inventories, variation in world production, devaluation of the U.S. dollar, and expanded, unpredictable fluctuations in foreign demand. These increased market risks together with growing use of debt capital have substantially increased financial risks for many agricultural producers. Hence, there is serious need to consider added demands for risk-bearing and to evaluate relevant choices for reducing, shifting, or otherwise managing these risks.

This paper evaluates the feasibility and structural implications of relevant risk responses available to producing firms that differ by size and type. Emphasis is given to the value of managerial information in formulating uncertain expectations and to the producer's financial and marketing choices for managing price risks. Others (e.g., Houck, Robinson) have focused more exclusively on public choices for achieving price stability.

Market and Financial Risks in Agricultural Production

Table 1 contains annual coefficients of variation for monthly prices of selected commodities over the 1959–74 period. They reflect irregular influences on prices, since the data were modified to account for estimates of seasonal price patterns in the respective commodities (Barry and Maberly). The increasing effects of irregular influences on intrayear price variation are clearly evident for crops and to a lesser degree for livestock. Coefficients of variation for monthly prices of wheat, corn, soybeans, and sorghum increased greatly in 1973 and 1974. For cotton, the increase started earlier. Price variability also increased for calves and fed cattle. The variability for hogs appears high although it was exceeded in some earlier years. Coefficients of variation for annual mean prices are also rather high, indicating considerable price movement between the years of the time series.

This increased price variability is carried by a production sector with relatively small operations that have been declining in number and increasing in size since the early 1930s. Most farms are organized as proprietorships or partnerships. Even farms that have incorporated have done so for flexibility in tax and estate management and tend to remain small. Only a relatively few larger operations have attracted substantial equity capital from outside investors.

Table 2 summarizes average balance sheets and income statements of the U.S. farm sector on a per farm basis for selected years. The aggregate changes provide insight into the changing financial structure of individual firms. Most of the sector's financing has been provided by borrowing and retained earnings, although leasing is also important. The more rapid growth of physical assets, especially real estate, relative to financial assets reflects a reduction in asset liquidity. Changes in liabilities reveal further loss of liquidity. Total debts per farm grew by over 1200% between 1950 and 1975—greater than the growth rates of total assets and net income—with real-estate debt expanding more rapidly than non–real-estate debt. Larger operations with younger operators appear to be relatively greater users of debt (USDA).

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Table 1. Coefficients of Variation for Monthly and Annual Mean Prices of Selected Agricultural Commodities, 1959–74

Year	Wheat	Corn	Soybeans	Sorghum	Cotton	Hogs	Calves	Fed Cattle
				Coefficient of Variation				
Monthly prices								
1959	.011	.043	.014	.057	.017	.099	.069	.058
1960	.006	.011	.045	.036	.027	.078	.065	.040
1961	.005	.024	.106	.064	.001	.005	.006	.010
1962	.023	.032	.008	.013	.001	.019	.011	.010
1963	.012	.044	.011	.011	.017	.060	.034	.044
1964	.085	.007	.040	.016	.023	.022	.079	.011
1965	.005	.022	.070	.008	.022	.183	.035	.049
1966	.044	.059	.083	.018	.008	.099	.025	.032
1967	.041	.026	.036	.038	.019	.074	.004	.017
1968	.025	.003	.020	.034	.030	.019	.006	.007
1969	.015	.045	.037	.042	.030	.105	.042	.058
1970	.034	.059	.055	.021	.053	.177	.026	.042
1971	.036	.061	.023	.056	.094	.058	.028	.020
1972	.008	.041	.071	.042	.193	.068	.052	.015
1973	.170	.274	.270	.191	.131	.154	.092	.090
1974	.195	.139	.160	.132	.199	.133	.275	.154
Annual mean prices	.409	.320	.480	.320	.288	.331	.172	.121

Much of the sector's equity growth has occurred as appreciation in current market values of land and machinery. Capital leasing especially of real estate has also contributed much to the financial growth of producing firms. In 1969 about 37.5% of total U.S. land was rented with nearly two-thirds of the rented land operated by part owners (Johnson).

Income data reveal the narrowing operating margins, the increasing debt per dollar of net income, and the increasing importance of off-farm income, especially for smaller operations. In 1950, for example, it would have required 0.9 year to repay total debt with the use of all net farm income. In 1974 it would have required nearly three years. Part of this net income must be consumed by farm families implying even longer payback periods.

The higher financial leverage and lower liquidity experienced by many agricultural

Table 2. Balance Sheet and Income State of the U.S. Farming Sector, Average per Farm, 1950–75

	1950	1955	1960	1965	1970	1974	1975
				($)			
Balance Sheet (Jan. 1)							
Assets							
Real estate	13,324	21,094	32,945	48,112	70,026	115,345	131,733
Non–real estate	7,305	10,624	13,958	17,029	25,874	44,943	42,205
Financial	2,807	4,031	4,561	5,774	7,729	9,456	10,607
Total	23,436	35,749	51,464	70,915	103,629	169,744	184,545
Liabilities							
Real estate	988	1,772	3,049	5,630	9,879	14,633	16,427
Non–real estate	1,217	2,023	3,203	5,336	8,072	11,675	12,609
Total	2,205	3,795	6,252	10,966	17,951	26,308	29,036
Equity	21,231	31,684	45,212	59,949	85,678	143,436	155,509
Income Statement							
Realized gross income	5,718	7,147	9,715	13,559	19,825	35,722	NA
Operating expenses (−)	2,973	3,969	5,815	8,517	14,872	22,173	NA
Net operating income	2,745	3,178	3,900	5,042	4,953	13,549	NA
Depreciation (−)	(472)	(795)	(1,094)	(1,523)	(2,288)	(3,760)	NA
Inventory change (±)	143	46	101	361	2	(578)	NA
Net farm income	2,417	2,429	2,907	3,890	4,667	9,211	NA
Off-farm income	NA	NA	2,140	3,792	5,874	9,232	NA

producers magnifies potential losses of their equity and increases difficulties in servicing debts and other financial obligations from variable cash flows and reduced credit reserves. A vivid example of the effects of increasing market and financial risks has been the financial plight of many cattle producers and feeders. Large losses of equity in highly leveraged operations occurred during late 1973 and 1974 from severe price declines. Lenders experienced serious problems in loan repayment and security. They now require higher margins of equity with greater credit analysis and control. Sources of outside equity declined greatly and have an uncertain future.

Theory and Methods of Risk Bearing

In an uncertain environment, theory suggests that a decisionmaker will choose among alternatives with outcomes expressed by probability distributions so as to maximize expected utility (Arrow, Dillon). The utility-maximizing choice rests on the decisionmaker's strength of belief, on the relevant characteristics (mean, variance, etc.) of the expected probability distributions, and on his personal valuation of the potential outcomes.

Risk-averse behavior results when the decisionmaker exhibits diminishing marginal utility for increases in expected wealth. This feature of economic theory implies that the disutility of losses outweighs the utility of gains when gains and losses are of equal magnitude and likelihood. Hence, the risk averter will value a risky alternative at less than its expected monetary value. In effect the difference between the expected monetary value and risk averter's value is a risk premium or cost of risk bearing required to convert the risky expectation into one that is certain. The greater is the aversion to risk, the higher is the risk premium. Moreover, the level of risk aversion, and therefore the size of the risk premium, are assumed responsive to changing wealth, experience, age, and other relevant factors. Empirical evidence (Cohn et al.; Gordon, Paradis, and Rorke; Arrow) suggests, for example, that absolute risk aversion generally decreases as wealth increases, although the wealth responses of relative risk aversion have been less clear.

Insight on risk responses have been gained through a variety of decision theories. Many recent advances are related to portfolio theory emphasizing means and variances of items comprising the portfolio (e.g., Lin, Dean, and Moore). The mean-variance approach is applicable if a decisionmaker's utility function reflects preferences only toward mean and variance of expected returns or if he regards uncertain outcomes as normally distributed. For an agricultural firm, the choices in production, marketing, and finance generate a portfolio comprised of physical and financial assets. An efficient set of portfolios results from business plans providing minimum variance of expected returns for various levels of returns. An optimal choice among the efficient portfolios provides maximum expected utility.

Portfolio adjustments refer to changes in an optimal portfolio that result from changing risk aversion and/or shifts in the efficient set caused by changing expectations on levels of risk, rates of return, or wealth (Robison and Barry). The expectations on increasing price variability cited earlier imply a shifting set of efficient portfolios for the producer that yield lower levels of expected return for the same level of risk carried prior to the increase. Hence, a revised optimal portfolio for the producer with constant absolute risk aversion (Arrow) will yield lower expected returns, risk, and growth. Even more adverse effects will occur for producers characterized by aversion to risk that increases as expected wealth declines.

These portfolio adjustments to increasing price variability reflect higher costs of risk bearing and add urgency to the producer's search for effective methods of cost reduction. Several factors make it difficult for producers to directly bear these risks. Low price and income elasticities for many commodities subject to weather and other uncontrollable events provide an inherent setting for relatively wide price fluctuations. Moreover, producers have little capacity for influencing resource and product prices. Opportunities for stabilizing expected returns through product diversification have been limited by few product choices with negative correlation of returns and by the economic gains lost from more specialized production. Producers are often left to draw on their accumulated wealth in periods of adversity. Increasing wealth provided by capital gains on real estate probably has decreased many producer's aversion to risk. But many others lack the necessary wealth, and even when available, their wealth tends to be very nonliquid.

A more viable kind of risk response includes

the opportunities for transferring risks to other economic units more willing and/or better able to bear the risks through their wealth, their ability to pool risks over numerous and diverse activities, or their ability to spread risks over numerous claimants. Arrow suggests, for example, that the government can effectively pool risks and spread its costs of risk bearing over such a large number of taxpayers as to reduce these costs toward zero (ch. 11). Arrow further characterizes market perfection in transferring risks as the emergence of marketing institutions for freely insuring against any economically relevant event with premiums determined by supply and demand for the contingency claims. He suggests that, when the market fails to achieve an optimal state of risk bearing, society will to some extent at least recognize the gap, and nonmarket institutions will arise attempting to bridge it.

For price risks in agricultural production, only a limited and imperfect set of market and nonmarket methods for risk transfer have emerged. Since the 1930s, price and income variability in agriculture were indirectly met by various price, income, trade, resource, and inventory programs of the government. However, the price-supporting features of many of these programs focused more strongly on increasing the level of farm income rather than reducing its variability. As a result, these programs often stimulated growth in production capacity, thereby compounding problems of supply management and income stability.

Recent modifications in government programs have shifted a large portion of the risk-bearing function from the public sector back to the private sector. Moreover, within the private sector much of the risk appears to rest with producers as opposed to input suppliers, product handlers, and retailers. This withdrawal of the public sector as a major risk bearer in agricultural production shifts emphasis to other markets for risk bearing—namely, markets for managerial information, financing, and commodities.

Building Management Information

As price and income risks increase in agriculture, producers will value more highly flows of new market and financial information that update and improve their expectations on future events. Hence, there will be increased demand for education and for hiring various kinds of information services. The information problem is likely more serious for crop producers who rely greatly on government programs in formulating market expectations. Many are ill-equipped to utilize market reports on currency devaluations, droughts, contracts for foreign grain sales, forward and futures contracts, etc. Livestock feeders could also use provisions of government programs in evaluating cost and availability of feed inputs, but like other livestock producers, they were more self-reliant in processing information on livestock prices.

The capacity to acquire and use new information likely varies with the producer's size of firm and its relation to other firms in the food system. The family farmer is typically a general manager concerned first with production, then marketing and finance. The wide range of management responsibilities limits his capacity to continually absorb and process new information. He relies greatly on general research and education offered by the public sector or on more specialized counsel provided by trade firms and lenders. He is likely to experience costly lags in adjusting his operation to a riskier environment.

Larger producing firms have tended to specialize and decentralize the management functions, allowing the firm to embrace a wider range of managerial services than is typically found in smaller farm proprietorships. These features characterize all types of growing firms, although they are especially evident in operations amenable to more industrialized production with greater market coordination. Specialization and internalization of management and information activities are a form of size economy that is not well documented in research. Some observers (e.g. Moore and Dean) cite serious competitive difficulties for smaller, family operations that need increasing public assistance to develop information systems comparable to those of larger firms.

The relatively small size and competitive environment of most producing firms creates disadvantages relative to farm-related market firms in building information. The larger size, commodity specialization, and greater market power of many input suppliers and product handlers provide considerable capacity to collect and utilize market information, thereby improving their market expectations. These factors lower the market firm's costs of risk bearing and may modify market risks as they are transmitted through the food and fiber system.

Financial Responses to Risk

Financial responses reflect the capacity to accept risks in marketing and production or to spread these risks among those with financial claims on the firm. In larger corporate firms, the wide dispersion of ownership helps to spread business risks over a large number of stockholders. The total costs of shareholders' risk bearing declines with increases in their number and as their share of wealth that is invested in the business remains small. However, the smaller producing firms in agriculture have little capacity for this kind of risk reduction.

When most resources were produced on farms and little debt was used, the brunt of adverse events was generally absorbed first in family consumption, then in partial liquidation of assets, and finally in emergency borrowing. In today's agriculture, the sequence is nearly reversed. Family consumption levels have risen and become less sensitive to variations in annual income. Purchased resources and increased capital investment have brought greater use of debt capital. Larger proportions of farm sales are now obligated to debt servicing, although off-farm income has increased as well. Hence, agriculture's financial responses to risk are now largely expressed in liquidity management and are influenced by the marketability of assets, borrowing capacity, and by terms on borrowing and leasing that modify variability in cash flows.

These financial responses to risk are still largely regarded in terms of defense or rescue mechanisms to be activated only in periods of adversity. If excluded from the mainstream of the producer's financial planning, they are uncertain as to their reliability and availability when most needed. In a more uncertain market environment, it seems reasonable to bring financial choices toward the forefront of risk management. The object is to make the financial environment more stable and predictable, enabling the producer to develop more formally financial plans for countering risks in his marketing and production environment (Baker). A more stable financial environment that can carry a greater share of agriculture's market risks will in turn reduce the need for stabilization programs that disrupt the operations of commodity markets (Baker).

Bringing financial choices to the forefront of risk management is not a simple task. Consider the choices in liquidity management. The assets of most producing firms are generally dominated by land, machinery, breeding stock, and other fixed assets whose liquidation would be costly. Even crops and livestock being produced are nonliquid due to long production periods and attachment to land. Highly liquid financial assets are rarely in portfolios of younger, expanding operations due to their large denominations and high opportunity costs. Moreover, access to high quality investment information is more limited in rural areas (Brake).

Greater reliance has been placed on the producer's borrowing capacity as a source of emergency funds in meeting variable cash flows. Evidence has suggested that producers seldom totally exhaust their borrowing capacity, even though higher leverage appears profitable (Barry and Baker). This reservation of borrowing capacity implies its value as a source of liquidity whose use does not greatly disturb the firm's asset structure or production organization. However, reliance on credit liquidity shifts a substantial portion of the firm's financial control to its lender. It is the lender who appraises the borrower's credit, setting limits on size and terms of loans in accord with his institution's legal requirements, availability of funds, and his risk-liquidity preferences. The credit evaluation may be tempered by the loan purpose and managerial practices of the borrower that affect quality of loan security and prospects of repayment. But, agricultural producers' skills in demonstrating credit worthiness—accounting, financial control, and cash and capital budgeting—have been slow to develop.

Increasing the capacity of financial markets to distribute agricultural market risks requires close alliance between rural lenders and larger money-market centers and adaptation of loan programs to more directly confront uncertain cash flows. Over time, commercial banks and other lenders in rural areas have improved their linkages with financial markets through use of liquid financial instruments and better communication. Examples include increased transactions in federal funds and overline participations between commercial banks and the favorable reception of bonds sold by the banks of the Farm Credit System. Still, there is concern with improving the availability of funds to rural areas, especially through the banking system (Federal Reserve Board of Governors). Proposals have included the establishment of secondary markets and pooling

mechanisms for agricultural loans. These proposals probably need evaluation in terms of their effects on risk bearing in financial markets as well as their effects on flows of funds.

Some agricultural lenders provide for principal deferral or advance payments on indebtedness, although these are seldom central features of the loan program. In addition, many non–real-estate lenders prefer to finance farmers solely on an annual basis carrying unpaid debts over to following years until they are fully repaid. Such loan practices leave the producer fully dependent on the lender's availability of funds and provide little capacity for the producer to adjust his financial organization to changing market conditions.

To provide this adjustment capacity, consider first an optimal loan program in a completely certain environment. The borrower would prefer minimum cost leverage with a maturity structure of debt that is roughly in accord with the payback periods for the items being financed. The result would be a set of self-liquidating loans with the respective assets pledged as security. In the more realistic, uncertain world, there is need for enough flexibility to lengthen and shorten these debt maturities in response to variable cash flows, and still provide lenders with adequate security. Hence, credit reserves must be large enough to provide additional loans to meet financial obligations in periods of adversity and flexible enough to convert excessive short-term debt into longer-term debt. Moreover, the loan program should be designed to restore a more acceptable debt structure when adverse conditions have passed.

This approach to financing under uncertainty utilizes the principles expressed in the income bond—essentially a loan with variable payments on interest—although extended here to amortized loans. The loan agreement could stipulate that payments of interest and principal be contingent on the magnitude of cash flows from the firm's operations. Debt servicing would be expected to adjust downward in periods of reduced cash flow and upwards in more favorable periods. Targets on payment levels, equity, and other measures of financial performance could be based on the borrower's financial strength and projected repayment capacity. Variations around the targets could be constrained within tolerance limits that are mutually acceptable to both borrower and lender. Detailed financial projections with periodic review would permit effective financial control. Such a program would demand complete and longer-term commitments by both lender and borrower, but it would formally accommodate variable cash flows and would likely contribute to improved financial management in agriculture. Financial risks would not necessarily change for lenders who have customarily used short-term commitments to finance their agricultural borrowers over unfavorable periods. Lending risks might even decline as experience with these programs is gained.

Other financial responses to increasing risks also warrant brief attention. Formal insurance (life, crop, and fire) provides a low cost source of contingent liquidity. However, insurance markets are generally limited in scope of insurable events, in extent of financial coverage, and even in freedom of action for the insured. In real estate leasing, crop and livestock share rents have been common and will likely warrant even more attention for their capacity to share expected income variability between tenant and landlord. Longer term leases also help to reduce tenure risk, as does leasing from multiple landlords.

Market Responses to Risk

A producer's market responses to risk include combinations of inventory management and forward commitments on prices and production with other participants in commodity markets. Inventory management refers to production and storage policies that influence the timing and magnitude of the producer's marketings and therefore largely affect risk bearing within the firm. Forward commitments on prices and production transfer part of the producer's price and yield risk to forward buyers or other speculators.

Inventory management can reduce risk through greater flexibility and/or more frequent, sequential marketing. Flexibility provided by storage permits the producer to hold commodities for favorable price movements. Moreover, buffer stocks from which sales would occur when yields are short of expectations and to which additions occur when yields exceed expectations provide for income stability over a series of marketing periods. Sequential marketing results in price averaging over the marketing periods, providing greater certainty in price expectations.

A producer's opportunities in sequential harvesting and marketings for perishable crops are limited by similarities in growing seasons for most crops. Geographic diversification of production over areas with different growing seasons may help provide sequential marketing for larger operations. For nonperishable crops, sequential marketing is provided by investment in storage facilities with sufficient returns expected to cover investment and operating costs. While substantial investment in on-farm facilities for grain has occurred in the corn belt and other areas, producers have only recently begun to consider sequential marketing as a viable strategy. It is still common for producers to hold large blocks of commodities in hopes of favorable price changes. Increasing irregularity in price movements makes this practice quite speculative.

For livestock, greater frequency in marketing requires less seasonality in production and feeding programs. Sequential marketing appears common in larger cattle operations and in many hog operations, especially those with substantial investment in production facilities.

Forward pricing arrangements can be used together with or separate from the producer's inventory programs. Forward contracts generally consist of the producer's promise to deliver a specified volume of production at a designated time, place, and price. The contract may or may not be associated with a commodity futures contract. The forward contract eliminates the producer's uncertainty of the future product price for that time period by transferring part of the price risk to the forward buyer. In turn, the forward buyer may hedge his position with others to transfer the risk further. In any event, the risk-bearing function is transferred to others who can likely accept it at lower cost due to their larger numbers, diversified portfolios, skills in market analyses, or risk preferences.

However, forward contracting does not completely eliminate risk in the producer's expected cash flow due to uncertain expectations on the future level of production. Shortfalls in yields can force the producer into the cash market at harvest to cover his contracted volume of production. Price and yield risk are jointly treated in a conceptual model developed by McKinnon to derive optimal levels of forward sales and inventories of buffer stocks for primary producers. The contracting decision is based on expected means and variances of prices and yields, and the criterion for optimality is minimum variance for a given level of income. Hence, the optimum is formulated as the desired level of contracting in a producer's portfolio decision.

McKinnon's model shows how the correlation between an individual producer's expected output and price, together with relative variabilities of yield and market price, can jointly determine the optimal contract. The model provides the following decision rules: the greater is price risk relative to yield risk, the greater will be the optimal forward sale, and the more highly negatively correlated are price and yield, the smaller will be the optimal forward sale. Hence, forward contracts hold greater potential for commodities with stable yields and geographically dispersed production. In addition, the adoption of yield-stabilizing practices will contribute to higher proportions of product contracting.

The producer's yield risk is more serious in forward rather than futures contracts owing to their lack of secondary markets and low market liquidity. Hedges in futures contracts that become partially speculative due to changing yield or price expectations can be adjusted prior to maturity. Moreover, the yield variability in primary production suggests lower levels of optimal contracting for individual producers than for forward buyers who can pool production risks over numerous, geographically dispersed producers and who may more easily gain risk premiums in their pricing policies.

McKinnon's analysis also indicates how producers can combine individual buffer stocks with forward sales to jointly mitigate the effects of price and yield variability on the firm's cash flow. He further argues that farmer-held buffer stocks and forward sales are more effective than farmer-held buffer funds or merchant-held buffer stocks for stabilizing the income effects of variations in agricultural production.

The extent of use of forward and futures contracts by primary producers is difficult to fully assess. Periodic studies of traders in commodity futures contracts have indicated a relatively low incidence of use by primary producers and even then speculation appears more prevalent than hedging. Data on the extent of forward contracting are also deficient. USDA estimates suggest extensive contracting in commodities amenable to capital-intensive, industrialized production: broilers, turkeys, vegetables, sugar, milk, and citrus

(Manley and Reimund). Cattle feeding has experienced increasing contracting, and some hog producers have experimented with contracting. Contracting in major grains and cotton was low in the past, although increasing in response to greater price variability (e.g., Nichols and Sporleder).

Some kinds and qualities of commodities do not have suitable futures contracts for hedging. Sorghum futures, for example, have not had sufficient volume to support a hedge. Some cotton does not fully meet quality specifications in commonly traded cotton contracts. Even delivery dates on futures contracts may not coincide well with expected harvest dates for many producers. Producers with these problems must either hedge in other contracts that correlate closely with their commodity's characteristics, use forward contracts, or refrain from contracting.

Indivisibility in sizes of futures contracts interacts with optimal levels of contracting to impose size restrictions on volume of hedging to the disadvantage of small firms. Consider, for example, a commonly used 5,000 bushel corn contract together with 50% contracting and yield expectations of 100 bushels. One hundred acres of corn are required to provide for one contract. If corn acreage comprises about half of the crop acreage as is common on many midwest farms, then a farm unit of at least 200 acres is needed for a single contract.

Hence, contracts appear more suitable for larger firms in the production sector. Furthermore, farm-related market firms may have comparative advantages in contracting. Larger, more specialized producers and trade firms experience more frequent market contact, handle larger volumes of production, and have greater capacity to collect and process market information.

One method of extending the market advantages of larger trade and production firms to primary producers is through marketing agreements offered by marketing cooperatives (Black and Knutson). The producer essentially contracts to transfer the functions of product storage and sale to the cooperative. Pricing is accomplished through pooling of cooperative returns with a partial payment when the product is delivered. The balance is payable at the end of the cooperative's marketing season. Frequent marketing by the cooperative helps to stabilize the producer's price expectations. Also, the cooperative's knowledge of commodity flows, larger size, and specialized management may even raise expected returns.

Interactions in Financial and Market Responses

It is reasonable to expect that a producer's market responses may interact with financial responses in developing a risk-management program. If expanding credit is important, the producer may adapt his level of contracting to accommodate his lender's preferences for the collateral and greater certainty of loan repayment provided by the contract (Barry and Willmann). For hedging with futures contracts, margin requirements in response to price changes through the hedging period require a flexible credit agreement. Buffer stocks may add further to credit by serving as loan security to lenders and providing greater assurance of product delivery to forward buyers. Hence, market choices that improve expectations on loan repayability may expand credit and/or reduce the producer's need for liquidity.

Structural Implications of Risk Responses

The feasibility of these risk responses appears to vary greatly with the producing firm's size, major enterprises, and quality of management. Nonetheless, several implications for size and financial and market structure of producing firms can be briefly explored.

Generally, success in reducing costs of risk bearing appears more likely in larger firms. Larger proprietorships and partnerships tend to have greater managerial capacity and easier access to commodity and financial markets for transferring risks. Hence, well-managed agricultural firms may find increasing opportunities for acquiring assets of other operators lacking the skills, temperament, or financial capacity to manage increasing market risks. However, the pace of such growth will depend greatly on costs of additional capital.

Implications for financial structure of producing firms depend largely on risk responses of capital costs, on modifications in financial markets to accommodate higher risks, and on the producers' financing strategies. Measuring the responses of capital costs to increasing risk is difficult in an industry comprised of

rather small firms with limited financial data who rely primarily on retained earnings and borrowing from rural lenders. Estimating changes in costs of retained earnings is nearly impossible to verify. Costs of equity capital for the few producing firms with stock traded on organized exchanges appear to have risen along with rising business risks in the early 1970s, but none of these firms attracted any significant amounts of new equity during this period. Interest rates on farm loans from the cooperative Farm Credit System, rural banks, and other lenders may increase to build reserves for expected loan losses, but these rates seldom vary among borrowers. The brunt of risk pricing for farm debt is expressed in terms of loan limits that differ among borrowers—a more inefficient and less effective pricing mechanism. Here, lenders' requirements for higher margins of equity, additional security, and other more conservative loan practices together with greater liquidity preferences by producers have added to the costs of using debt.

Hence, for most family-size operations, it appears that relatively greater costs of debt capital will initially prompt shifts to lower leverage in their liability structure. However, larger operations may grow relatively faster by reducing risks through choices in markets for information and commodities and perhaps by spreading risks with equity capital markets. The potential impacts of these risk responses on financing institutions are also important. As an example, the increased borrowing needed by larger producers will increase pressure on the size, organizational structure, and portfolio management of lenders both to provide the financing and manage the greater risk.

In commodity markets, increasing use of forward commitments to transfer price risks may significantly alter market structures for commodities that have been characterized by open market exchanges. The price controls provided by forward contracts could seriously distort the signals for resource adjustment and the distribution of rewards from production and risk bearing. More stringent terms on nonmarket linkages may also alter managerial control in agriculture. Control of decisionmaking for producing and marketing commodities could increasingly shift out of the production sector. So could resource ownership. Alternatively, group action by producers through cooperatives or other means of commodity pooling may retain decision control in the production sector and lead to prices at least partially administered by producer. In either case, the terms on which supply responds to price would be modified. So would the performance of agricultural markets.

In summary, risk management requires resource commitments whose costs likely vary by size, type, and organization of firm. Moreover, there may be important comparative advantages among farms and between farm and market firms in managing risks. This paper has focused primarily on risk responses in markets for managerial information, finance, and commodities for distributing risks. Yet the public sector is also a candidate for risk bearing, and clearly the costs of national and international programs stabilizing farm prices and incomes must be compared with the costs of other means of risk bearing.

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Discussion of Research Implications

Clifford Hildreth

Having grown up in Kansas during dust storms and an undisguised depression, I am perhaps not quite as horrified by Gray's list of horrors as some younger colleagues might be. Unsettled commodity prices do not seem as hopeless as prices that have firmly settled near zero. However, I do share his and others' deep concern and their hope that economists can make useful contributions to the resolution of current difficulties.

Both Gray's and Barry and Fraser's papers have cited urgent reasons to consider adjustments to uncertainty at this time. Market developments have made government price guarantees irrelevant at a time when foreign demand has become more uncertain and more important. It is also a time when the high cost of capital and the greater need for debt financing make many firms particularly vulnerable. Uncertainties about our government's trade policies compound the difficulties.

These special needs seem to be accompanied by special opportunities. Emergence of problems may well have created some political flexibility. Cogently reasoned new proposals may receive more serious consideration than in settled times. Gray's citation of the broad mandate to the Commodity Futures Trading Commission might be taken as one indication.

I was asked to comment on research implications. First, let me express some views on theoretical developments and then some conjectures on possible applied projects. As indicated by Barry and Fraser, many economists believe that the most promising current theoretical approach is one that assumes the decisionmaker acts to maximize his expected utility. I concur. However, one has to realize that, despite significant advances in the past two decades, almost all expected utility formulations of economic problems involve highly restrictive simplifying assumptions. This does not mean that applications should not be made. It means that applications have to be made with considerable judgment and conclusions treated as tentative unless strong verifying evidence can be adduced.

For example, many logical objections have been raised to mean-variance analysis, and these seem generally convincing. However, there may be many situations in which mean-variance analysis may reveal the most important considerations in a contemplated application in simple, accessible form. The situation reminds me somewhat of discussions of a Marshallian partial equilibrium analysis a few decades ago. Partial equilibrium analysis is logically incomplete and is sometimes misleading but, when applied with care and judgment, often gives a good initial grasp of a problem and is still usefully employed. Similarly, I believe mean-variance may often furnish a useful start for analyzing a problem, but possible shortcomings should be carefully considered before conclusions are regarded as firm.

To strengthen applications, much further research is needed on the nature of relevant utilities and personal probabilities. Barry and Fraser cite studies that suggest that decreasing (with wealth) absolute risk aversion may be typical of individual utility functions. This has generally been presumed, but we need to continually seek further hints and evidence on such questions. If the presumption is generally true, are there recognizable exceptional circumstances? Does it apply to both private decisionmakers and corporations? What about other kinds of institutions?

A simple example of a theoretical proposition that can be misleading if the special assumptions under which it was derived are not borne in mind is the oft-quoted assertion that "the risk averter will value a risky alternative at less than its expected monetary value." This conclusion arose in models in which the decisionmaker was assumed to have fixed initial wealth. It remains true if the decisionmaker initially has an uncertain prospect that is stochastically independent of the risky alternative being considered.

However, if the risky alternative promises

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to reward the risk-averting decisionmaker under circumstances in which his wealth would otherwise be relatively low and penalizes him under more favorable circumstances, it will be valued at more than expected monetary value. A familiar case is property insurance. The return is risky—many people pay premiums a long time without receiving anything, the expected money return is negative, but many risk averters buy property insurance because the prospective positive return occurs under circumstances in which the need is great. Typical commodity hedging is another example.

A decisionmaker with really certain initial wealth could hardly exist in the real world and I believe relations between initial prospects and new alternatives are typically important so such relations have been emphasized in theoretical models I have begun to consider (e.g., Hildreth).

Particularly interesting cases of risk averters being willing to pay more than subjective actuarial value occur if there is an event that would be harmful to one decisionmaker and beneficial to another. If the parties hold the same subjective probability for the event, then the first decisionmaker is willing to pay more than actuarial value for a contract under which the second party compensates him if the event occurs. The second is willing to sell at less than actuarial value. There is a traders' surplus somehow to be shared.

A closely analogous but slightly more complex situation would occur if a vegetable grower who did not have access to a futures market sold forward to Gray's institutional feeding firm that failed to hedge supplies. Both parties would stabilize income prospects and, if they were risk averters, the seller would be willing to sell below the break-even price and the buyer willing to buy above. The situation seems worth distinguishing from one in which each party sells to a speculator who charges a risk premium. When the original parties deal directly, it would seem more appropriate to refer to "cancellation of risks" rather than "passing of risk from seller to buyer." If there were many growers and feeders who dealt through a futures market rather than individually, the situation would be essentially unchanged. To the extent that markets can be organized to bring together traders who have complementary risks of this type, speculators and risk premiums are not needed.

In applied research, a major need is to supplement recent theoretical discussions of contingent commodity and contingent money markets with research into the feasibility and potential value of specific possibilities. One example, the possibility that futures markets might offer contracts in which the quantity delivered is dependent on weather experienced, has been suggested by Sandor. This prospect could be investigated along with research on other extensions of futures markets suggested in both papers presented today. Extensions to new commodities, new traders, and new geographical areas are contemplated.

Concerning new traders for existing markets, it is widely said that, for agricultural products, the volume of forward trading is much greater than futures trading. This does not seem necessarily bad, but the possibility that extended futures trading would be beneficial deserves careful study. Gray indicates that assured compliance with the agreed terms was the main incentive in the establishment of futures markets. This is clearly of continuing importance, but I wonder if the fact that the futures market exposes each trader's offer to many potential traders and thus brings about some general balancing of supply and demand may be of comparable importance.

As things stand, both of these advantages of a well-organized general market may be lost by forward traders who have special needs or who are geographically less accessible. With modern computers and communications, I wonder if futures markets could usefully expand by offering both buyers and sellers a wider variety of more specific contracts, providing more frequent and specific delivery dates, more indicators of quality, and a larger array of possible delivery points. Some contracts might have buyer's options, others seller's options, and still others might be quite specific on both sides.

I cannot, of course, presume to know how much forward trading that is now individually negotiated could economically be encompassed in organized futures by such extensions. It does, however, seem to me a very worthwhile area for research. In addition to the advantages of reinforcing the integrity of contracts and offering each trader more exposure to others, such extension should make futures quotations still more representative of general demand and supply conditions and, by increasing both volume and potential volume, make short-term movements less influenced by actions of large traders. It

seems likely that extension of markets in this way would place a severe strain on pit trading and that a system of computer matching of offers to buy and sell under specified terms would likely be needed. To progress in such investigations, descriptive studies of current forward trading is needed as an early step.

Gray's suggestion concerning new geographical areas for trying to extend the advantages of futures trading to international markets is very appealing. Difficulties such as governments of major trading countries abound, but the advantages to all concerned in having assured access to a market that represents current needs and costs reasonably well should be very persuasive if careful research verifies them and they are coherently explained.

I also find the Barry-Fraser discussion of alternative risk-abating devices for primary producers quite stimulating and believe their account contains guides for interesting and productive research. Projects to find risk-complementary or at least risk-independent enterprises to combine on farms should be challenging. Attempts to attract nonfarm industries whose activity would not be tied to local farming receipts would be good for the entire regions concerned, as well as furnishing nice labor hedges for small part-time farmers.

Diversified enterprises and/or combined small farm, off-farm activities may have aesthetic appeal for some people. Formal economics deliberately ignores the technology of consumption and the utility of production. Perhaps much is sometimes lost in this way. Such a possibility might well be explored in researching these alternatives.

Another Barry-Fraser proposal, the design of financial instruments that would provide the kind of flexible payment loans they envisage, sounds to me like a very worthwhile and challenging enterprise. The inverse correlation between need for loans and eligibility as determined by existing financial institutions has been frequently noted. Making credit available when needed while protecting both parties will certainly be productive if it can be achieved. Perhaps some government participation will be found needed and justified.

In general, I found both papers stimulating and informative. The suggestions regarding pooling, reserves of liquidity or goods, leasing, and information services deserve careful discussion and research, but I have neither the time nor preparation to offer constructive observations at this stage.

I would like to close with two miscellaneous observations. As we analyze response to uncertainty more completely, I suspect our analysis will become part of our general economic analysis rather than a separate field. Uncertainty pervades all activity, and it seems unlikely that we can satisfactorily separate decisions involving uncertainty from general decisionmaking except in our present very preliminary stages. The other miscellaneous point concerns Gray's final contrast between risk aversion and risk selection. As viewed by current theory, there is no need for this distinction. As observed by Barry and Fraser, a risk averter has diminishing marginal utility for income or wealth. This does not mean that he refuses to take risks, but that he chooses those which seem justified either because they offer sufficient opportunities for reward to outweigh the dangers of losses and/or they offer circumstances for gains and losses that are complementary to the decisionmaker's present prospects and thus tend to stabilize prospective wealth.

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Discussion of Market Implications

Konrad Biedermann

The two papers presented at this session contain many points with which I can only agree, but also some thoughts with which one can take issue. In line with this, I would like first to share some thoughts that occurred to me while reading the two papers, and then add some observations made from my specific vantage point as financially-oriented researcher and investment analyst in a major agribusiness firm.

The Barry/Fraser paper focuses on increased price variability for the farmers' products as an indicator that financial risk in primary agricultural production has increased. Furthermore, the paper discusses risk management primarily in terms of minimizing price variability and stabilizing expected returns. I contend that price variability, in itself and without reference to the corresponding cost of production, does not prove that the probability of incurring a financial loss has increased. It merely establishes the fact that it will statistically be more difficult to obtain the highest price possible. As a case in point, aggregate net farm income during the years 1973 and 1974 has reached unprecedented heights, both in absolute dollars and in relation to assets employed. This was not the result of a very sudden increased sophistication on the part of farmers to deal with the greater product price variability.

The coefficients of variation for the annual mean prices shown in table 1 of the Barry/Fraser paper are meaningless in my opinion because they are influenced heavily by the length of period selected for analysis and by the underlying secular trend in price levels. The paper points to a growth of over 1200% in debt per farm between 1950 and 1975 and a payback period of nearly three years for this debt as indicators of decreasing ability of the farm sector to absorb financial risks. But comparing statistics from the U.S. Department of Agriculture's *Balance Sheet of the Farming Sector 1974* with comparable data for the Grain Processing Industry (SIC 2041) and the Agricultural Merchandising Sector, it becomes evident that these other sectors operate on a smaller gross profit margin and a much thinner cushion of financial reserves. This is what made it mandatory for them to devote major efforts to the task of risk management. Considering relative strength of net worth, it would take only a small fraction of the unhedged decline in the price of commodities to completely wipe out the net worth of a merchandising firm, compared to the decline necessary to completely dissipate the net worth of the farmer (see table 1).

Barry/Fraser also suggest that more frequent sequential marketing can reduce risk, which is correct if we assume that risk aversion is the ultimate goal. But sequential marketing does not optimize prices. It is an averaging procedure that only guarantees that something better than the lowest price will be obtained. Maybe this explains why pooling results achieved by the cooperatives, as well as by the Canadian and Australian Wheat Boards, have been mediocre at best.

Professor Gray's paper emphasizes institutional factors and the role of organized futures markets. I agree with his comments both in regard to the value of these institutions to our society and to the limitations still remaining. But in regard, for instance, to the lack of a sorghum futures contract, a broader definition by the Commodity Futures Trading Commission of bona fide hedging could do much to alleviate the present problem. Cross-hedging sorghum in corn futures gives essentially as much price protection as can be obtained hedging corn in corn futures.

Another problem mentioned is the need for added margin calls to hedgers during periods of adverse price movements. It would seem there should be an objective reappraisal of using commodity options to deal with this problem. (Obviously, I would be opposed to dealing in "naked options.") The hedger would in effect have already purchased with the option all additional margin potentially due if the market changes required it.

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Table 1. Approximate Financial Structure of Agribusiness Sectors

	Farming Sector[a]	Manufacturers of Grain Mills Products[b]	Wholesalers of Grain[c]
Total sales (%)	100	100	100
Cost of sales (%)	74	89	90
Gross profit (%)	26	11	10
Net worth per $ of sale	$4.02	$0.17	$0.09

[a] USDA.
[b] Robert Morris Associates, p. 60, SIC 2041.
[c] Robert Morris Associates, p. 119, SIC 5153.

Professor Gray's paper also refers to the Chicago delivery problem and a need for multiple delivery points. It may be just a matter of semantics, but it seems to me we have and want to maintain a futures market with a single pricing point but with alternative delivery points. We now have this situation for Chicago Board of Trade wheat, corn, oats, soybean oil, and soybean meal futures.

Use of futures markets has played a key role in the ability of the trade to handle price risk. But there are other agricultural market risks that also have increased greatly during the last few years. While these risks have been enlarged by the greater price variability of recent periods, they often cannot be shifted to speculators through such mechanism as a futures market. Risk management in these areas often requires an adjustment of internal procedures and tighter management controls. I shall try to list just a few of them.

The grain trade has always prided itself on the fact that contracts to buy or sell were honored by all sides, with defaults being a very rare occasion, even though initially they were made verbally and only later confirmed in writing. On the buying side, however, our industry did experience a very pronounced increase in defaults by farmers who had forward contracted for the sale of their crop during the spring and summer of 1972 and then did not deliver at harvest time. This, of course, was a period of rapidly rising prices, and for those firms who had hedged these volumes in the futures market in anticipation of applying them to already incurred sales, this led to significant losses. As a result of this experience, our industry has become more selective when screening the capability and willingness of prospective forward contractors to actually perform, regardless of the magnitude of price movements between contract time and harvest. Ultimately, performance could be guaranteed by some kind of escrow payment, which, of course, would tend to increase marketing costs.

The incidence of contract defaults on the buying side in our business has declined again, and in retrospect these losses have been of much lesser magnitude than the ones caused by subsequent contract defaults on the part of some foreign governments. Probably the largest case occurred when the Turkish government in March 1975 refused to open letters of credit for the delivery of purchases they had made during the latter part of 1974, when price levels had been some 25% higher. The potential loss on that contract alone on a fully hedged basis had been reported in the press as over $30 million. Even though international courts in London have, in the meantime, upheld the validity of the contract, it will be nearly impossible for a private firm to collect from an unwilling and uncooperative foreign government. Again, these experiences have led to a distinct tightening of contract provisions, especially the insistence of immediate opening of letters of credit on the part of the foreign buyer. This, of course, adds to the cost of the commodity and the ultimate price the recipient is, in effect, paying.

The higher price levels and greater variability in prices also make it difficult for processors and marketing firms, as well as for the farmer, to closely estimate their future credit needs and cash flows. As a result, all of these firms must arrange beforehand for larger credit lines than they may actually need. To the extent that a commitment fee is required for standby credit lines, this increases the cost of performing the marketing function.

Still another kind of new risk has been created by the need to maintain greater levels of fixed investment at a time when the firms themselves have become increasingly subject to disruptive outside influences. These outside influences make it extremely difficult to fully and effectively utilize the larger investment. For instance, as a result of the shortage of rail transportation equipment, over the last ten to fifteen years the grain merchandising and processing industries have come to purchase or lease over 50,000 covered hopper cars. Mileage earnings from the railroads cover only a part of this new long-term financial commitment. However, greater availability of on-farm storage (which is welcomed as a leveling influence in marketing volumes throughout the

year) combined with great price variability make it possible for farmers to completely hold their grain off the market for certain periods. This makes level and continuous use of this expensive transportation equipment impossible to achieve for our industry.

As another example, export elevators have been requiring additional investment for air pollution control and for upgrading of handling speeds to load large bulk-carrier ships faster. But there is less ability on the part of the industry to plan for continuous and effective use of these expensive tools because such developments as government embargoes on export shipments or boycotts of longshoremen of foreign flag vessels can close down these facilities unexpectedly and for indefinite periods. All of these risks, of course, add to the cost of doing business.

But it would be wrong to conclude from all this that the increased financial risk has worked to the distinct disadvantage of the industries involved or that a socialist or centrally planned economy would be much better equipped to cope with it. Farm income has never been higher than in the last three years, and, to date, the processing and marketing firms have been able to generate the new capital required to cope with the increased volume and higher price levels. Furthermore, the American consumer still is getting his food at a substantially lesser percentage of his disposable income than people in any other country around the world. At the same time, agricultural exports from the United States made a very crucial positive contribution to our balance of foreign trade.

Risk, when properly managed, holds opportunities for gains, as well as losses. Based on the record of all of the participating industries, risk management (availability of tools, as well as extent of use) has been successful to date. While there will always be room for improvement, it is to the credit of our economic system that it permits industries to flourish under these conditions.

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Discussion of Policy Implications

Richard L. Sandor

In this discussion, my assignment is to evaluate briefly the policy recommendations made in the papers by Barry and Fraser (hereafter B-F) and Gray, as well as developing the policy implications that are not specifically made by the authors. Although both papers contain interesting questions related to policy, there is a paucity of specific recommendations. Therefore, subsequent parts of this discussion will be devoted to discussing the questions as well as considering policy recommendations and implications.

The B-F paper explicitly recognizes the increased market risks that confront producers and qualitatively examines risk responses according to the size distribution of primary agricultural producers. The discussion includes both financial and market responses to risk. Market responses that include inventory management and forward contracts appear to be less available to the small producer. There have been market reactions to the need and demand of the small producers such as the creation of cooperatives. These institutions provide an alternative to the small producer for using arrangements and institutions that may not be available to the firm on an individual basis. Policymakers should be aware of the social value of these institutions in formulating policies that may affect their operations. Although cooperatives provide some solution to the problems of the small producer, they may be insufficient. The authors quite properly emphasize the need for greater management and information among producers in the current market environment. The implicit and explicit references to increased levels of education is particularly worth noting. Public universities have traditionally provided support for producers through the development of degree programs oriented toward producers as well as extension activities. However, the emphasis on production to the exclusion of marketing and finance that was proper in an environment characterized by price support programs is currently inappropriate. It appears reasonable to suggest that this inadequacy of the system be confronted directly and that policymakers define specific programs to meet the current needs of producers. This is particularly important to the small producer with management limitations.

B-F present the argument that institutional arrangements such as the size of futures contracts provide a constraint to the small producer, i.e., indivisibility imposes disadvantages to the small producer. In this regard their paper should contain reference to the MidAmerican Commodity Exchange, which has contracts that are smaller than those on the Chicago Board of Trade and other exchanges, e.g., a corn contract of 1,000 bushels versus 5,000 bushels. Consequently, according to their analysis a farm unit of only 40 acres and not 200 is necessary for a single contract. Although there has been some concern about the proliferation of futures contracts, the Commodity Futures Trading Commission should be particularly aware of the potential value of the multiple trading of contracts of the same commodity but of different size.

Another point worth noting is the recommendation of the authors that there be greater ties between rural areas and major money market centers. This was particularly important in 1973 when significant margin requirements were necessary to finance even modest short hedges. More efficient ties in the capital markets would tend to diminish the possibility of a regional credit crunch. Furthermore, it would seem desirable for bankers in money market centers throughout the country to understand organized futures markets to improve the flow of capital in this sector. There are probably a wide variety of reasons that cause futures markets to exhibit an intertemporal price structure with more than full carrying charges, but inadequate knowledge of these institutions may be a contributing factor. The intent of Congress with respect to the

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educational function of the CFTC is particularly worth noting in this context.

High margin requirements, low liquidity, and reduced financial leverage described by B-F mitigate against the use of organized futures markets. There appears to be a policy that could be implemented by regulators and legislators that might be implemented to facilitate risk transfer. As B-F state, "Arrow further characterizes market perfection in transferring risks as the emergence of market institutions for freely insuring against an economically relevant event with premiums determined by supply and demand for the contingency claims." It appears that the preceding is a rational argument for legally permitting the trading of options on futures markets. A market test of this concept might be used to determine if options could be used as a means for insuring against certain economically relevant events. If it appeared feasible, then one can imagine the possibility of trading more complicated contingent contracts on organized exchanges, e.g., an option on a futures contract that is exercisable under certain weather conditions. Of course, liquidity limitations would probably limit any proliferation of contingent contracts.

The Gray paper raises many interesting policy questions rather than making specific recommendations. Subsequent comments will simply be devoted to briefly commenting on them rather than developing lengthy implications for policy based on hypothetical answers. Our organization will follow his outline.

In contrast to the B-F paper, Gray emphasizes certain institutional factors accompanying the change from governmental mechanisms to the marketplace for risk transfer. Gray quite accurately describes how organized futures markets absorbed the increased risk. The difficulties associated with the inability of the markets to completely facilitate the transfer of risk among nonprimary producers may also be explained in terms of inadequacies in human capital. The analog is the lack of exposure of corporate management to futures markets in degree and extension programs in schools of business administration and management. The educational function of the CFTC as well as the universities should both be mentioned at this point.

It seems appropriate within this discussion paper to digress briefly on a particular reference of Gray's regarding the possibility that the lack of hedging may require some regulatory oversight. It appears worthwhile recommending that extreme caution be pursued in implementing any recommendation regarding limitations on what risks, if any, decisionmakers should be permitted to assume in their own operations. Of course the latter must be considered in the context of firms honoring legal contracts.

An extremely important aspect of the Gray paper is the statement regarding "official neglect of the sanctity of contracts." The impact on holders of futures contracts was only the first of many effects of the grain export embargo. The introduction of greater uncertainty into the system by such events create greater costs for society. The effectiveness of market responses to risk, such as hedging, is clearly reduced when the markets become subject to certain types of political decisions. A curious side effect of the embargo may have been the achievement of the exact opposite effect than was intended. Latent demand by foreign nationals for agricultural commodities may have been released as a result of greater uncertainty regarding the United States as a source of supply.

Some of the more important policy implications in the Gray paper emerge from the discussion of the CFTC. The intent of Congress was that increased regulation was necessary to preserve and promote the integrity of the free market. As a brief aside, it is certainly a curiosity that Congress would retain a law banning futures trading in onions while reaffirming its belief in this mechanism. It will also be interesting to observe if a regulatory agency whose raison d'etre is the promotion of competitive markets will seek market solutions in the course of performing its regulatory function. A related but different question is concerned with the eventual ratio and/or composition of staff economists to attorneys in an agency in which a significant portion the responsibility resides in determining the economic justification for contract markets. In both of these areas the commission has significant opportunities for innovation within the regulatory framework.

The discussion of the Chicago Board Options Exchange and the Government National Mortgage Association mortgage interest-rate futures contract leads one to inquire into the proper relationship between regulatory bodies. Regulatory agencies in protecting their

jurisdiction may impose significant costs on industry and the taxpayer. The need to clearly define the authority of regulators may not only require a resolution in the courts but a greater degree of coordination. It seems reasonable to wonder if innovation is aided or hindered in a system that requires significant expenditures both by the private and public sector to determine who should regulate an activity rather than what the objectives of regulation should be. A significant portion of our research and development for interest-rate futures was devoted to developing a contract within an uncertain regulatory environment. The fact that the Securities and Exchange Commission still claims jurisdiction not only imposes additional costs but may even threaten the success of the market by imposing uncertainty on principals and agents operating on the exchange.

The implication that certain problems, such as the Chicago delivery problem, may be resolved under regulation must be viewed cautiously since the proposal accepted by the Commission was a modification of the one originally submitted to the Commodity Exchange Authority. A question regarding the proliferation of new contracts on several exchanges still has to be determined. It is essential that competition among exchanges with regard to its impact on promoting inventive activity be understood by the CFTC.

Gray raises some interesting questions in the section on "Some Remaining Problems." Is the market test of survival sufficient economic justification for a futures market? What is the optimum level of hedging? These and other unanswered questions may also have significant policy implications.

One final point regarding organized futures markets and cartels emerges throughout the paper. If organized futures markets have provided the effective risk transfer mechanism described by Gray, the policymakers should promote the uses of this mechanism wherever possible rather than support international agreements. Further but limited evidence of the role of organized futures markets in promoting price stability and providing a market test of price expectations suggests an even greater reliance on this mechanism.

The purpose of this discussion has been to emphasize some of the more important questions raised in the B-F and Gray papers as well as examining policy implications. Answers to the numerous questions raised by the authors should provide significant value to policymakers in formulating the legal and regulatory environment of futures markets.

Notes

Implications of Short-Run Rising Average Productivity in Cattle Feeding

Ewen M. Wilson

The recent period of high grain and low cattle prices has inspired renewed questions about economic efficiencies in cattle feeding. Unfortunately, despite solid theoretical foundations and some empirical investigations (Heady and Dillon, O.E.C.D., Heady et ai.), agricultural economists appear unable to reach a consensus. The initial inclination arising from usual production and marginal substitution criteria is to prescribe a move down the production function (less feed for less gain) and/or dilution of high energy rations with lower energy and lower cost ingredients (a downward shift of the production function). This note proposes to demonstrate that the first prescription is inappropriate and that the second is questionable and inappropriate within narrow delimitations specified here.

In particular, there is evidence that cattle feed-gain response functions do not fall in stage II of production. Zulberti, Reid, and Casler have inferred from animal nutrition work (Blaxter, Dodsworth) that cattle feeding is constrained by appetite limitations to the rising average physical product portion of the production function (stage I of production). Their use of British Agricultural Research Council nutritional information to test the hypothesis has led them to conclude that "for feeds of any given concentration the producer has only to decide between feeding *ad libitum* or not feeding at all" (Zulberti, Reid, and Casler, p. 10). Brokken has provided an excellent review of the net energy system suggested by Lofgreen and Garrett and subsequently adopted as beef-cattle feeding recommendations by the National Research Council of the National Academy of Sciences (hereafter NRC). Brokken et al. have recently employed this system in a fairly broad framework to look at the feed-energy concentration issue, an issue that they conclude remains unresolved. Nevertheless, their results tend to lean in the direction of higher rather than lower energy cattle feeds as do the earlier results of Heady et al.

The specific objectives of this note are to use the NRC system to test the stage I hypothesis and to analyze relative economic efficiencies of two energy-specific rations. The focus is upon feed-gain relationships and cost curves for a steer of given weight on a daily basis. No attempt is made to address the more complex, longer term questions of overall economic efficiency in cattle-feeding operations. The latter questions are, without doubt, important. They are also difficult to answer. In the search for less ambiguous answers, this note confines itself to a narrower framework. Nevertheless, the daily feed-gain relationships portrayed here are, in effect, underlying components of the feed-gain trajectory over time. In this sense, they are directly relevant to longer term feedlot profit analyses. (See Brokken et al.)

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Conceptual Framework

The NRC system expresses energy needs of beef animals of given liveweight in terms of daily net energy requirements for maintenance plus daily net energy requirements to sustain a specified rate of gain. Feedstuff energy concentration is measured as net energy available for maintenance and net energy available for gain (both expressed on the basis of a unit dry matter feed).

Dividing cattle energy requirements by the appropriate feed energy concentration values yields

$$(1)\quad f = [A + Bg/2.2 + C\,(g/2.2)^2]\,(W/2.2)^{0.75},$$

where $A = A'/\epsilon_m$, $B = B'/\epsilon_g$, $C = C'/\epsilon_g$, f = daily feed requirements (pounds dry matter), g = liveweight gain per day (pounds), W = liveweight of the animal (pounds), ϵ_m = net energy concentration of the feed for maintenance (megacalories per pound dry matter), ϵ_g = net energy concentration of the feed for gain (megacalories per pound dry matter), and where $A' = 0.077$, $B' = 0.05272$, and $C' = 0.00684$.[1] The alternative form of equation (1) is

$$(2)\quad g = 2.2\,\{-\gamma + [\gamma^2 + (f/(W/2.2)^{0.75} - A)/C]^{0.5}\},$$

where $\gamma = B/2C$.

Thus, for a suitable cattle-feeding ration of known analysis (energy concentration), the total daily gain function, for an animal of specified

[1] Parameter values (A', B', C') are taken from NRC and pertain to steers (NRC, p. 3). A factor of 2.2 has been used to convert kilogram units to pounds. For heifers, $B' = 0.05603$ and $C' = 0.01265$. The present analysis is confined to steers.

liveweight, may be determined as a function of daily feed, while average and marginal daily gain functions are g/f and $\partial g/\partial f$, respectively. In order to cast these production relationships in an economic framework, it is only necessary to know the ration price when total daily feed cost may be expressed as

$$F = Pf/k, \tag{3}$$

where F = total daily feed cost ($ per day), P = cost of the ration ($ per pound "as fed"), and k = fraction dry matter of the feed. Average and marginal daily feed costs with respect to gain are F/g and $\partial F/\partial g$, respectively. These production and cost relationships have been computed and are plotted in figures 1 and 2 for two rations specified in table 1. Based on NRC formulas, ration 1 contains approximately 70% total digestible nutrients (TDN), while ration 2 contains slightly less than 76% TDN (National Academy of Sciences, p. 19). Ration costs are based on $2.60 per bushel corn, $50 per ton hay, and $170 per ton supplement.

Appetite Constraint

In theory, if cattle could be induced to consume larger quantities of feedstuffs of higher energy content, they would effectively move down the average feed-cost curve and up the average physical product curve. In practice, physical barriers to feed intake and liveweight gain do exist. A crude rule of thumb commonly encountered in the cattle industry is that cattle consume daily between 2% and 3% dry matter equivalent of their body weight. For instance, the *Feed Industry Red Book* uses a 16- to 17-pound dry matter intake range (2.75% body weight average) for 600-pound steers rising to a 23-

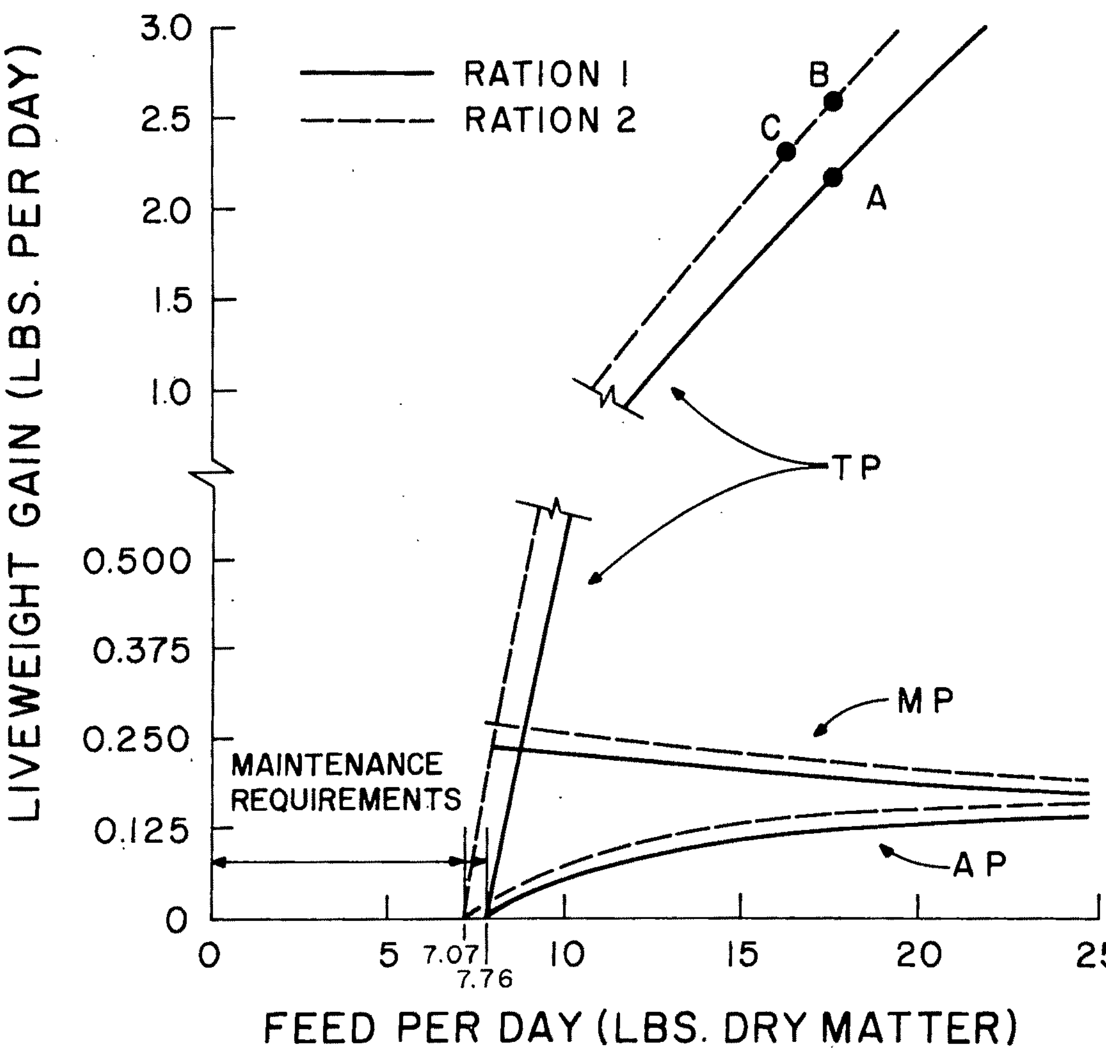

Figure 1. Total (TP), average (AP), and marginal (MP) production relationships for 700-pound steer on alternative rations

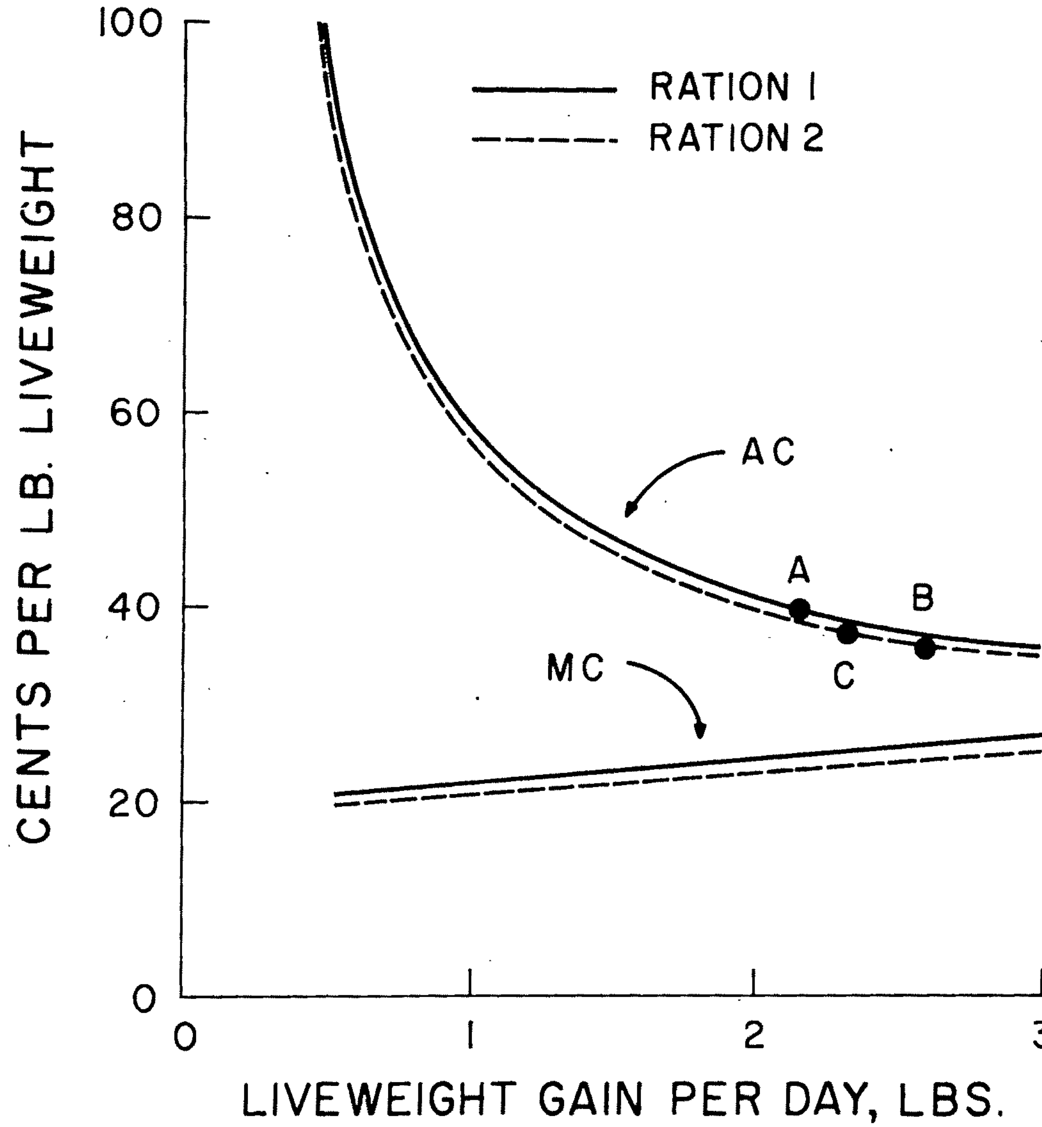

Figure 2. Average (AC) and marginal (MC) feed cost curves for 700-pound steer on alternative rations

to 25-pound range for 1000-pound animals (2.4% average).

If it were assumed that regardless of feed-energy concentration, 700-pound steers consumed 17.58 pounds of dry matter per day (just over 2.5% body-weight equivalent), then the predicted gain rate for ration 1 would be 2.2 pounds per day (point A in figure 1) versus 2.6 pounds for ration 2 (point B). On this basis one might be tempted to conclude that the higher energy ration is more efficient (higher average physical product) and less costly per pound gain (A versus B in figure 2) than the lower energy ration. In fact, such a conclusion would be premature since it ignores the effect of different feedstuff energy concentrations on voluntary appetite. In practice, daily dry matter intake of low energy (high roughage) rations is limited by rumen capacity. However, as energy concentration of the ration increases, there comes a point where rumen capacity ceases to be limiting but where chemostatic and thermostatic factors take over to inhibit daily dry matter intake (daily physiological energy requirements are satisfied within rumen capacity limitations). The latter phenomenon is widely accepted in the literature (Montgomery and Baumgardt, Dinius and Baumgardt, Elliott and Reed, Brokken and Dinius), although the exact causal mechanism is not fully understood (Elliott and Reed).[2]

[2] The feed energy level at which rumen capacity ceases to be the limiting factor was estimated by Dinius and Baumgardt to be 2.47 Mcals DE (digestible energy) per kg. dry matter for sheep and was reassessed by Brokken and Dinius at 2.82 Mcals per kg. dry matter for cattle. Using relationships described by the NRC,

Table 1. Composition and Analyses of Two Cattle-Fattening Rations [a]

	Ration 1	Ration 2
Ingredients (% "as fed")		
Corn grain	58	75
Orchardgrass hay	32	15
Protein supplement [b]	10	10
Complete ration	100	100
ϵ_m (Mcals/lb dry matter)	0.7473	0.8209
ϵ_g (Mcals/lb dry matter)	0.4490	0.5132
Crude protein (%)	12.40	12.46
Dry matter fraction	0.8888	0.8899
Cost (¢/lb "as fed")	4.34	4.71

[a] Based on NRC analysis.
[b] Proprietary brand protein-mineral supplement analyzing 90% dry matter. 50% crude protein and 0.6182 and 0.3455 Mcals net energy per lb. dry matter for maintenance and gain, respectively.

Based on regression of experimental data, Brokken et al. have provided a quantitative evaluation of the relationship, which can be written as

$$(4)\quad f_v = (0.094138 + 0.0625/\epsilon_g)\ (W/2.2)^{0.75},$$

where notation is unchanged from before except that f_v denotes voluntary daily dry matter feed intake in pounds. Evaluated for 700-pound steers, equation (4) yields a daily dry matter voluntary intake of 17.58 pounds for ration 1 and 16.27 pounds for ration 2 (points A versus C in figures 1 and 2).[3] Use of these points to compare the two rations indicates that despite the higher unit cost of the higher energy ration, the latter still has an advantage over the lower energy ration in terms of average feed cost (37.4¢ versus 39.7¢) and average physical product (0.142 versus 0.123). In terms of feed conversion efficiency (pounds feed per pound gain), which is in effect the inverse of average physical product, the comparisons are 7.06 versus 8.12 on a dry matter basis, or 7.94 versus 9.14 on an "as fed" basis (corrected for dry matter fraction).

Effect of Varying Prices

The preceding section supports the hypothesis that cattle-feeding production relationships are constrained by appetite limitations to stage I of production and indicates that, at the stated feed prices, the higher energy ration is preferred from an economic efficiency viewpoint. The next logical step is to analyze the effect of variations in price of the energy-rich ration ingredient (corn) upon relative economic efficiencies of the two rations. The object is to determine whether the increasing cost of the higher energy ration relative to the lower energy ration is sufficient to offset the physical efficiency advantage of the higher energy ration.

The feedlot operator is interested in returns over feed costs to other feedlot costs (labor, veterinary, medicine, interest, transport, and marketing fees) and to fixed overheads (depreciation on facilities, taxes, and the like). Assuming that he perceives an expected market price for his cattle, then it is appropriate to compare the daily margin between this expected price and daily feed costs as a measure of relative economic efficiency of the two rations. If the expected cattle price is denoted by R dollars per pound, then daily margin over feed costs, π dollars per head, may be written in terms of earlier notation as[4]

$$(5)\qquad \pi = Rg - F.$$

Total daily feed margin is shown in table 2 for a range of cattle prices ($35, $40, and $45 per 100 pounds) and corn prices ($2.20 up to $3.80 per bushel), where equation (4) has been used to establish appetite level and g and F have been calculated from equations (2) and (3), respectively. Other feed ingredient prices are unchanged from before ($50 per ton orchardgrass hay, $170 per ton protein supplement).

For the range of cattle and corn prices employed in table 2, the higher energy ration has the advantage except when corn prices are $3.80 per bushel and cattle prices $35 per 100 pounds, in which case the lower energy ration has a slightly lower negative margin. This price combination is for all practical purposes untenable (it represents a steer-corn ratio of 9.2).[5]

From table 2 the effect of a 1¢ per bushel rise in corn prices on daily feed margin is −0.245¢ for the higher energy and −0.205¢ for the lower energy ration. The effect of a $1 per 100-pound rise in cattle price on daily feed margin is 2.32¢ and 2.16¢ for the respective rations. For the period 1950 through 1972, the standard deviation for corn prices was 18.35¢ per bushel and for cattle prices $4.16 per 100 pounds.[6] These standard deviations can be

these values convert to 0.2341 and 0.3594 Mcals net energy for gain per lb. dry matter, respectively (NRC, p. 19).

[3] Daily dry matter intake relationships are commonly expressed by animal scientists on a per unit metabolic weight basis. That is, in our notation, $f_v/(W/2.2)^{0.75}$. (See Dinius and Baumgardt.) When equation (4) is substituted into equation (2), daily liveweight gain becomes a function of energy but independent of weight. The implications are that cattle on a specified energy concentration feed grow at a constant rate of gain but diminishing feed efficiency (lbs. feed per lb. gain). Brokken et al. indicate that the constant rate of gain assumption causes very little aggregation error over the entire feeding period. In any event, these implications are of secondary importance here, since equation (4) is being used purely to establish feasible appetite reference points for comparison of the two rations.

[4] The emphasis here is upon profit per unit time rather than profit per unit weight gain as in Brokken et al. Equation (5) is conceptually analogous to their partial derivative of total revenue with respect to time minus their partial derivative of total cost with respect to time.

[5] For the period 1950–72 the mean steer-corn ratio measured as annual average choice steer prices at Omaha ($ per 100 lbs.) divided by annual average corn prices recieved by farmers ($ per bushel) was 22 with a coefficient of variation of 0.18 (USDA 1973, 1972).

[6] Based on the price series cited in note 6, the mean steer price for the period 1950–72 was $26.63 per 100 lbs. (with standard

Table 2. Feed Costs and Daily Margin over Feed Costs for a Range of Cattle and Corn Prices, 700-Pound Steers on Alternative Rations

Corn Price ($/bu.)[a]	Ration Cost (¢/lb.)[a]	Marginal Cost of Lb. Gain (¢)	Average Cost per Lb. Gain (¢)	Daily Margin (¢/day) over Feed Costs When Cattle Price ($/100 lbs.) Is 35	40	45
Ration 2						
2.20	4.2	21.0	33.1	4.3	15.9	27.4
2.60	4.7	23.7	37.4	−5.5	6.1	17.6
3.00	5.2	26.4	41.6	−15.2	−3.7	7.8
3.40	5.8	29.0	45.9	−25.0	−13.5	−2.0
3.80	6.3	31.7	50.1	−34.8	−23.3	−11.8
Ration 1						
2.20	3.9	22.3	35.9	−1.9	8.9	19.7
2.60	4.3	24.7	39.7	−10.1	0.7	11.5
3.00	4.8	27.0	43.5	−18.3	−7.5	3.3
3.40	5.2	29.4	47.2	−26.5	−15.7	−4.9
3.80	5.6	31.7	51.0	−34.7	−23.9	−13.1

[a] On "as fed" basis.

used as crude weighting factors to estimate the relative effects of corn and cattle prices on daily feed margin. Thus, the weighted effects on daily feed margin of increases of 1 ¢ per bushel corn and $1 per 100-pound cattle are −4.50 and 9.65, respectively, for the higher energy versus −3.76 and 8.99 for the lower energy ration. Evidently cattle-price changes have potential for greater effect on daily feed margins (and therefore feedlot profit) than do corn-price changes. The implication is that as cattle and corn prices trend upwards over time daily feed margins will improve.[7] (It is also likely that other feedlot costs will inflate over time, offsetting the benefit of increased daily feed margin.)

Conclusions

The widely accepted NRC system has been used to demonstrate that cattle feeding is constrained by voluntary appetite to stage I of production, where the production function is expressed as the daily feed-gain relationship for rations of specified energy density. More specifically, feed-gain relationships appear to be confined, for practical purposes, to the rising average product portion and the diminishing marginal-product portion of the production function (beyond the point of inflexion of the total product curve). The implication is that in a positive profit situation cattle ought to be fed for maximum daily gain, since this is equivalent to the lowest attainable point on the average cost curve.

When two rations of different energy concentrations were compared, the higher energy ration was preferred on grounds of physical and economic efficiency over a relevant range of corn and cattle prices. Although based on a 700-pound steer, these results appear to hold for a range of feasible animal weights (not reported here). Results would be strengthened by comparison of a wider selection of rations and ingredients.[8] Nevertheless, they do indicate, in the short run at least, that maximum profit (minimum loss) is attained with higher rather than lower energy rations (presumably with ingredients selected on basis of least cost).[9] In the case in which cattle prices fall below average feed costs per unit gain, the decision reverts to one of "full-feed versus no-feed" since daily appetite limitations preclude movement down the average feed-cost function.

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deviation 4.16) and mean corn price 123.48 ¢ per bushel (standard deviation 18.35).

[7] This may be confirmed by comparing daily feed margins for cattle at $45 per 100 lbs. and corn at $3 per bu. (15.0 steer-corn ratio) and cattle at $40 per 100 lbs. and corn at $2.60 per bu. (15.4 steer-corn ratio).

[8] Below a certain energy concentration level, equation (4) would not be appropriate for determining voluntary appetite due to rumen fill limitations (see note 3).

[9] The emphasis may change in a longer run feedlot profit analysis in which additional factors such as time costs and changing grade-price relationships are taken into account, or where alternative systems in a multienterprise framework are compared. Brokken et al. suggest that roughage (lower energy) fares better when profit per head rather than profit per unit time is the optimizing criterion.

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An Economic Analysis of the U.S. Poultry Sector

Dale Heien

During 1973 consumers experienced the sharpest food-price inflation in the United States since World War II. Food prices rose an estimated 16%. Contributing substantially to the increase in food prices was poultry, which increased 40%. Price increases for poultry in 1974, while not as large as in 1973, were again substantial. Beef, pork, and poultry constitute the major portion of U.S. protein intake with consumption at 110.8, 62.2, and 50.5 pounds per capita, respectively, in 1973. Poultry consumption comprises turkey (8.9 pounds per capita in 1973), broiler chickens (37.6 pounds per capita), and "other" chickens (4 pounds per capita). The 1973 total of 50.5 pounds is up substantially from the 24.2 pounds in 1950. One reason for this increased consumption is the long-run decline in poultry prices from 1950 to 1972 mainly as a result of low corn and soybean prices, and the increased demand for "fast food" outlets. Poultry occupies a relative importance of 4.1% in the food-at-home portion of the consumer price index for 1973 compared with 12.4% for beef and veal and 7.3% for pork. Approximately 3.5% of farm income comes from poultry operations, with Georgia, Arkansas, Alabama, and North Carolina ranking as the largest producers. The industry is characterized by a high degree of vertical integration, so much so in fact that it is difficult to identify the farm price of poultry. Also, the industry is highly concentrated (for the agricultural sector) with 47% of broiler production being accounted for by the top twenty firms in 1968 (USDA).

This note briefly describes an econometric model of the U.S. poultry economy. The model is then used to measure the impact on the poultry economy (in both the short and long run) of changes in various key influencing factors, such as aggregate income and price level, the price of close substitutes (beef and pork), and cost variables including corn and soybean meal prices. Next, the poultry price inflation of 1973 is analyzed by decomposing the overall price changes into the sum of the various influencing factors.

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Description of the Model

The model of the poultry sector presented here involves seventeen endogenous variables and ten exogenous variables. The poultry economy is composed of three products, turkeys, broilers (young chickens), and other chickens (hens, surplus cockerels, and fowl from egg-producing flocks). Each product sector contains a retail demand equation, a farm-level demand equation, a production relation, and a stock equation. Total supply for each product is specified as a function of the farm (or wholesale) price for that particular product, the feed-cost variable (a weighted average of corn and soybean meal prices), the wage rate for that industry, an industry-capacity measure (a proxy for capital stock), and a time trend for technical change. The price and cost variables are entered as ratios in the supply relations in order to preserve homogeneity. This is in keeping with the theoretical specification of supply curves in terms of relative prices (Walters). Frequently, agricultural supply response relations are fitted without this restriction. The main justification for not using ratios is that data do not exist on all input costs. In the absence of complete input cost data, both approaches produce biased estimates. However, the ratio form will be tractable in terms of the bias. Also, the ratio form increases the degrees of freedom.

Total consumption for each product is then determined by subtracting exports, military purchases, U.S. Department of Agriculture donations (all exogenous), and ending stocks from total supply. Relations for ending stocks were obtained by specifying average stocks held during the year as a function of total output and a time trend to account for improved inventory procedures over time. Since the model is based on annual data, there is very little fluctuation in stock levels from year to year. This is understandable since short-run stock fluctuations average out over the course of a year as production and orders are adjusted to demand at the retail level. Given these stock equations, the quantity side of the model is complete.

Retail prices for each product are estimated as price-dependent demand relations. The demand for each product is specified as a function of the normalized price of that product and the normalized price of competing products (beef, pork, and all

other goods). Normalized prices (prices divided by per capita money income) were chosen for several reasons. First, they are theoretically more satisfying in terms of the mixed demand systems implied by price-dependent relations (Heien, Samuelson). Second, they conserve on degrees of freedom and hence alleviate somewhat the multicollinearity problem. Third, as an empirical matter, they tend to outperform relative-price real-income price-dependent demand systems in a predictive sense. Farm-level prices were also estimated in a price-dependent manner. These relations specify the ratio of the farm price to the retail price as a function of the output of each product and the ratio of the retail price to input costs such as wage rates and feed prices. Such relations may be termed price-dependent derived demand curves for factor inputs (Heien).

Model Estimates and Evaluation

The model was estimated by ordinary least squares (OLS) using annual data from 1950 to 1969. The main reason for not using a simultaneous technique is the near recursive nature of the model. Also, although OLS estimators are biased in a simultaneous equation context, so are all other estimators. Given the small sample and the sensitivity of simultaneous techniques to specification error, which is always present, full-information techniques are questionable.[1] The numbers in parentheses below the coefficients are the t-ratios. The numbers below the t-ratios are the elasticities at the means.

$$ZC = 0.00168 - \underset{\substack{(5.80)\\0.82}}{0.00027\,TCCBC/POP} + \underset{\substack{(2.34)\\0.15}}{0.155\,ZBEEF} + \underset{\substack{(4.89)\\0.35}}{0.379\,ZPORK} - \underset{\substack{(4.02)\\1.28}}{1.37\,ZAO} + \underset{\substack{(4.18)\\0.23}}{0.0164\,ZWPCEB},$$

$\bar{R}^2 = 0.998$ S.E.E. = 0.15E−04 D.W. = 2.75.

$$ZTURK = 0.0866 - \underset{\substack{(2.34)\\1.07}}{0.0049\,TCCT/POP} + \underset{\substack{(0.35)\\0.21}}{12.13\,ZFISH} - \underset{\substack{(0.82)\\1.27}}{62.65\,ZAO} - \underset{\substack{(0.49)\\0.30}}{0.000158\,TSFB/POP} + \underset{\substack{(1.89)\\0.60}}{32.91\,ZC},$$

$\bar{R}^2 = 0.944$ S.E.E. = 0.0024 D.W. = 2.29.

$$(TCCCEB/POP) = 1.48 + \underset{\substack{(2.18)\\2.78}}{22888.6\,ZC} - \underset{\substack{(1.23)\\0.94}}{552.2\,ZWPCEB} + \underset{\substack{(1.72)\\2.40}}{24951.0\,ZFISH} - \underset{\substack{(2.30)\\3.50}}{30823.4\,ZAO},$$

$\bar{R}^2 = 0.887$ S.E.E. = 0.97 D.W. = 1.75

$$(WPBC/RPC) = 20.98 + \underset{\substack{(10.19)\\0.26}}{10.14\,RPC/WRPP} - \underset{\substack{(2.79)\\0.22}}{(0.171\text{E}{-}08)\,TCCBC} + \underset{\substack{(1.98)\\0.07}}{2.43\,RPC/FCV} + \underset{\substack{(3.41)\\0.22}}{0.647\,t},$$

$\bar{R}^2 = 0.978$ S.E.E. = 0.401 D.W. = 1.35.

$$FPT = 7.59 + \underset{\substack{(6.83)\\0.83}}{0.364\,RPT} - \underset{\substack{(2.32)\\0.15}}{(0.28\text{E}{-}08)\,TCCT},$$

$\bar{R}^2 = 0.884$ S.E.E. = 1.05 D.W. = 1.88.

$$WPCEB = -5.75 + \underset{\substack{(10.00)\\1.67}}{22.25\,RPC} - \underset{\substack{(5.41)\\0.25}}{0.332\,t},$$

$\bar{R}^2 = 0.979$ S.E.E. = 0.82 D.W. = 2.14.

$$TPBC = -0.293\text{E}{+}10 + \underset{\substack{(3.42)\\0.36}}{(0.508\text{E}{+}08)\,(WPBC/FCV)_{-1}} + \underset{\substack{(1.67)\\0.11}}{(0.169\text{E}{+}08)\,WPBC/WRPP} + \underset{\substack{(0.69)\\0.28}}{(0.113\text{E}{+}09)\,t} + \underset{\substack{(1.52)\\0.95}}{0.905\,CAPBC},$$

$\bar{R}^2 = 0.995$ S.E.E. = 0.134E+09 D.W. = 1.54.

$$TPCEB = 0.148\text{E}{+}10 + \underset{\substack{(0.53)\\0.06}}{(0.492\text{E}{+}07)\,(WPCEB/FCV)_{-1}} + \underset{\substack{(0.86)\\0.12}}{(0.106\text{E}{+}08)\,(WPCEB/WRPP)_{-1}} - \underset{\substack{(2.91)\\0.98}}{(0.102\text{E}{+}09)\,t} + \underset{\substack{(3.26)\\0.42}}{(0.336\text{E}{+}07)\,t^2},$$

$\bar{R}^2 = 0.973$ S.E.E. = 0.545E+08 D.W. = 1.78.

$$TPT = 0.798\text{E}{+}09 + \underset{\substack{(1.97)\\0.56}}{(0.351\text{E}{+}08)\,(FPT/FCT)_{-1}}$$

[1] Two-stage least squares (2SLS) often produces estimates identical to OLS, due to the high degree of correlation between each endogenous variable and the set of exogenous variables used as instruments, i.e., the first stage R^2's are all near 1.0 There is considerable evidence that 2SLS produces estimates with greater bias in small samples where the exogenous data are highly correlated (Johnston).

$$+ \underset{\substack{(6.07)\\0.38}}{(0.586\text{E}+08)\, t} - \underset{\substack{(1.75)\\0.51}}{(0.256\text{E}+08)}\,(WPBC/FCT)_{-1},$$

$\bar{R}^2 = 0.908$ S.E.E. $= 0.102\text{E}+09$ D.W. $= 1.89$.

$$ESBC + ESBC_{-1} = 0.517\text{E}+08 + \underset{\substack{(4.12)\\1.61}}{0.04858\, TPBC} - \underset{\substack{(3.33)\\1.02}}{(0.123\text{E}+08)\, t},$$

$\bar{R}^2 = 0.844$ S.E.E. $= 0.41\text{E}+07$ D.W. $= 1.98$.

$$ESCEB + ESCEB_{-1} = 0.218\text{E}+09 + \underset{\substack{(0.80)\\0.17}}{0.025\, TPCEB} - \underset{\substack{(3.42)\\0.37}}{(0.563\text{E}+07)\, t},$$

$\bar{R}^2 = 0.776$ S.E.E. $= 0.93\text{E}+07$ D.W. $= 1.50$.

$$EST + EST_{-1} = 0.172\text{E}+08 + \underset{\substack{(1.73)\\1.06}}{0.314\, TPT} - \underset{\substack{(0.06)\\0.01}}{(0.680\text{E}+06)\, t},$$

$\bar{R}^2 = 0.628$ S.E.E. $= 0.386\text{E}+08$ D.W. $= 1.22$.

$$TSBC = TPBC + ESBC_{-1}.$$
$$TSCEB = TPCEB + ESCEB_{-1}.$$
$$TST = TPT + EST_{-1}.$$
$$TCCBC = TSBC - ESBC - XBC.$$
$$TCCT = TST - EST - XT.$$

The variables used above are defined as follows, where the symbol + designates exogenous variables. $CAPBC^+$ = capacity in the broiler industry, computed using peak-to-peak method; $ESBC$ = ending stocks of broiler chickens; $ESCEB$ = ending stocks of chicken except broilers; EST = ending stocks of turkey; FCT = feed cost variable for turkey production, $0.75(PC/1.12) + 0.25(PSM/2.8)$; FCV = feed cost variable for broilers and chicken except broilers, $0.65(PC/1.12) + 0.35(PSM/2.8)$; FPT = farm price of turkey; PAO^+ = price index of all nondurables and services, except beef, pork, poultry, and fish; PC^+ = price of corn; $PCENDS^+$ = personal consumption expenditures on nondurables and services; POP^+ = U.S. population; PSM^+ = price of soybean meal; RPB^+ = retail price index for beef; RPC = retail price index for frying chicken; RPF^+ = retail price index for fish; RPP^+ = retail price index for pork; RPT = retail price of turkey; t = time trend (1950 = 1.0, 1951 = 2.0, etc.); $TCCBC$ = total civilian consumption of broiler chicken; $TCCCEB$ = total civilian consumption of chicken except broiler; $TCCT$ = total civilian consumption of turkey; $TPBC$ = total production of broiler chicken; $TPCEB$ = total production of chicken expect broilers; TPT = total production of turkey; $TSBC$ = total supply of broiler chicken; $TSCEB$ = total supply of chicken except broiler; $TSFB^+$ = total supply of fed beef; TST = total supply of turkey; $WPBC$ = wholesale price of broiler chicken; $WPCEB$ = wholesale price of chicken except broiler; $WRPP^+$ = wage rate in the poultry processing industry; XBC^+ = military purchase of broiler chicken plus exports of broiler chicken plus USDA contributions; XT^+ = military purchase of turkey plus exports of turkey plus USDA contributions; $ZAO = PAO/(PCENDS/POP)$; $ZBEEF = RPB/(PCENDS/POP)$; $ZC = RPC/(PCENDS/POP)$; $ZFISH = RPF/(PCENDS/POP)$; $ZPORK = RPP/(PCENDS/POP)$; $ZTURK = RPT/(PCENDS/POP)$; and $ZWPCEB = WPCEB/(PCENDS/POP)$.

In order to provide some form of evaluation for the model, a prediction interval test outside the sample period was performed. The results are given in table 1.

Analysis of the Poultry Economy

One of the important analytic results of any econometric model is the impact effects. Tables 2 and 3 present reduced-form elasticities for both short- and long-run models. The elasticities give the percentage change in selected endogenous variables as a result of a 1% change in various exogenous variables. Elasticities are used since reduced form multipliers are difficult to interpret due to dimension problems. The long-run elasticities give the impact of a sustained change over several periods in any exogenous variable. Since lagged variables (mainly prices) play a significant role on the supply side, the long-run multipliers are of considerable interest.

Table 1. Actual (A) and Predicted (P) Percentages of Change in Selected Endogenous Variables, 1970–73

	TPBC		*TPT*		*RPC*		*RPT*		*WPBC*		*FPT*	
Year	A	P	A	P	A	P	A	P	A	P	A	P
1970	7.9	8.0	8.7	6.9	−3.2	−14.0	14.6	5.8	−9.0	−8.9	−3.4	6.0
1971	0.2	1.9	2.8	4.0	1.0	−3.4	−2.3	−9.3	3.0	−2.3	−2.2	−9.7
1972	5.4	6.5	7.1	2.5	1.0	−5.8	1.3	0.7	3.0	−10.6	0.5	0.2
1973	−1.5	1.7	0	0.5	44.3	45.0	32.9	41.9	50.2	53.1	54.5	36.4

Table 2. Short-Run Reduced Form Elasticities

Exogenous Variable	Endogenous Variables					
	TPBC	*TPT*	*RPC*	*RPT*	*WPBC*	*FPT*
RPB	0.01	0	0.26	0.21	0.31	0.25
RPP	0.03	0	0.75	0.71	0.89	0.72
PCENDS	0.06	0	2.34	2.68	2.84	2.42
PAO	−0.10	0	−2.30	−2.52	−2.74	−2.21
PC	0	0	0	0	0	0
PSM	0	0	0	0	0	0
WRPP	−0.02	0	0.14	0.07	0.19	0.02
PFISH	0	0	0	0.30	0	0.30
XBC	0	0	0.14	0.07	0.19	0.06

Table 2 reveals the overall structure of the model. Since supply relations contain mainly lagged variables, there is very little short-run sensitivity on the part of these relations. The price (or demand) side of the model is quite sensitive to demand "shifters" such as income and substitute meat prices. Consider, for example, the demand relation for broilers, written for expository purposes in double log form as

$$(1)\quad ZC = TCCBC^{-0.82}\, ZBEEF^{0.15}\, ZPORK^{0.35}\, ZAO^{-1.37}\, ZWPCEB^{0.23},$$

which in view of the definition ($ZC = RPC/PCENDS$, etc.) can be written as

$$(2)\quad RPC\text{-}TCCBC^{-0.82}\, RPB^{0.15}\, RPP^{0.35}\, PAO^{-1.37}\, WPCEB^{0.23}\, PCENDS^{1.64}.$$

The elasticity of *RPC* with respect to *PCENDS* of 1.64 is simply the first round effect. This increased price for broilers then increases the demand for other chicken and turkey, in turn causing increases in *RPT* and *WPCEB*. The increase in *WPCEB* causes a "second round" increase in *RPC*. Since the elasticity of *WPCEB* with respect to *RPC* is 1.67, the total increase in *WPCEB* will be 2.74 (1.67 × 1.64). This increase of 2.74% will then cause a second round increase in *RPC* of 0.63. Hence, the first and second round effects so far are 2.27. Before going to the third round, it should be noted that increases in *WPBC* (as a result of increases in *RPC*) will increase supply and hence tend to lower *RPC*. At each successive round, these effects become smaller and smaller until they vanish numerically and a solution is reached. Table 2 gives the final outcome of the cumulative total of these first, second, third, and so on, round effects, which in the case of *RPC* is 2.34. The big impacts are caused by changes in *PCENDS* and *PAO*. In the long run, increases in prices call forth a supply response, which in turn tends to dampen prices. Hence, the long-run reduced-form elasticities for the price variables tend to be lower than their short-run counterparts, while the opposite is true for the quantities.

To continue the above example, the 1% increase in *PCENDS* that caused a 2.34% increase in *RPC* in the short run also caused *WPBC* to rise by 2.84%. In the next time period, the increase in *WPBC* causes an increase in *TPBC* of 1.02% (2.84 × 0.36). This increase in production will increase supply, which will, through the demand relation, lower *RPC* by 0.84% (1.02 × 0.82). These effects produce a second year solution, which is then fed in as a lagged endogenous variable into the third year solution and so on, until once again the changes vanish numerically. The cumulative sum of all of these yearly changes are the long-run elasticities, which in the case of *RPC* − *PCENDS* is

Table 3. Long-Run Reduced Form Elasticities

Exogenous Variable	Endogenous Variables					
	TPBC	*TPT*	*RPC*	*RPT*	*WPBC*	*FPT*
RPB	0.02	0.03	0.18	0.22	0.20	0.20
RPP	0.09	0.08	0.51	0.66	0.58	0.58
PCENDS	0.20	0.08	1.59	2.16	1.86	1.95
PAO	−0.20	−0.07	−1.62	−2.07	−1.83	−1.87
PC	−0.02	−0.02	0.08	0.07	0.09	0.06
PSM	−0.03	−0.02	0.11	0.08	0.13	0.08
WRPP	−0.03	0.01	0.07	0.02	−0.06	0.02
XBC	0.01	−0.01	0.09	0.06	0.12	0.06
PFISH	0	0.05	0	0.27	0	0.23

Table 4. Decomposition Analysis of Retail Broiler Price (RPC) Changes in 1973

	PCENDS	*PAO*	*RPB*	*RPP*	*PFISH*	FCV_{-1}	*t*	Other	Error	Actual
% change, 1973	10.8	4.50	19.3	33.0	14.7	9.2	4.5	—	—	44.3
Elasticity	2.34	−2.30	0.26	0.75	0	0.23	−0.28	—	—	—
Contribution	24.8	−10.4	5.0	24.8	0	2.1	−1.27	—	−0.73	44.3

1.59. Tables 2 and 3 are a clear portrayal of this self-equilibrating mechanism, which is characteristic of agricultural products whose supply responds to lagged product prices.

It is now possible, using the results contained in table 2, to analyze the causes of the substantial rise in broiler and turkey prices in 1973. Taking the elasticities for the major exogenous variables and multiplying each times the percentage change in that variable gives the contribution of each variable to the overall price increase in 1973. Tables 4 and 5 present this decomposition analysis for retail broiler and turkey prices, respectively.

Table 4 indicates that, in the case of broiler chicken, the effects of all exogenous variables except beef, pork, and fish prices would have resulted in a price increase of 10.2 percentage points. The remaining 34.1 percentage points of the 44.3% increase was accounted for by increases in beef, fish, and (mainly) pork prices. Hence, three-fourths of the price increase for broilers was a result of increase in prices of substitute meats. Increases in fish prices are due mainly to supply problems that appear unrelated to current economic problems, mainly the time required to build new capacity in the industry and increase worldwide competition for fish. The large increases in pork prices (33% in 1973) are due in large part to the effect of decreases in the hog-corn ratio in 1971 and 1970. During those two years, the ratio of hog prices at the farm level to the price of corn fell 25.3% and 6%, respectively. Based on a study by Heien, the effect of these price-ratio declines accounted for a substantial portion of the decline in hog slaughter in 1973. The same is true for beef production, although in that case increases in the current price of feed grains were equally influential. Increases in the current price of feed grains were equally influential. Increases in feed costs in 1972 were largely responsible for the decrease in broiler production in 1973. It is also true that the very large increases in feed costs in 1973 had some effect on that year's production, although the statistical estimates failed to show any significant current year effect.

Decreases in the supply of beef (−4.6%), pork (−7.3%), and chicken (−2.2%) accounted for a substantial price increase through the "own price" effect. Based on calculation of this model and those for pork contained in Heien and for beef in Heien and Matthews, the supply reduction (of beef, pork, and chicken) due to effects of lagged price ratios accounted for 14 percentage points of the increase in broiler prices. The general inflationary pressures (money income and the price of all other goods) accounted for an additional 14.6 percentage points in broiler prices. The increase in fish prices resulted in a 4.6% rise. Of the remaining 11%, −5.6 percentage points are due to "time." The residual, 16.7 percentage points, may be ascribed to the effect on the demand for broilers of increased beef and pork prices, which were themselves the results of increased broiler prices. In other words, as beef prices increase due to short supplies of beef, the demand for broilers shifts, resulting in increased broiler prices. These increased broiler prices in turn raise the demand for beef again, resulting in further beef price increases, which then further raise broiler prices through their effect on broiler demand. The year 1973 was perhaps the only time in the postwar U.S. economy when the supplies of all three major protein items shifted downward simultaneously, thus making the usual substitution among meat and poultry extremely difficult. If one accepts the above analysis, then the role of current feed prices is considerably less than commonly thought. While it is true that increased feed costs do affect beef supplies (since cattlemen can bypass feed lots if corn prices are too high), their effect on broiler and pork supply is much less in the current period. Also not mentioned above (because of its nonquantifiable nature) is the impact of the 1973 price freeze on meat and poultry supplies. Unfortunately, the freeze effects are forever confused with the feed-cost increases and a sorting out of the two appears unlikely.

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Table 5. Decomposition Analysis of Retail Turkey Price (RPT) Changes in 1973

	PCENDS	*PAO*	*RPB*	*RPP*	*PFISH*	FCV_{-1}	*t*	Other	Error	Actual
% change, 1973	10.8	4.5	19.3	33.0	14.7	9.2	4.5	—	—	32.91
Elasticity	2.68	−2.52	0.21	0.71	0.30	0.13	−1.52	—	—	—
Contribution	28.9	−11.3	4.0	23.6	4.4	1.2	−6.8	−2.1	−9.0	32.91

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Projecting Performance of Farm Supply Retailing Firms Using Simulation Techniques

E. M. Babb and L. A. Lumpkin

Previous research used experimental gaming in a laboratory setting to test hypotheses about business behavior of firm managers as subjects (Babb and Bohl 1974). Subject managers were from midwestern farm supply retail outlets. This paper analyzes the implications of the behavior observed in the Babb and Bohl gaming experiments for future performance and organization. The objectives are to project which types of organizations are most likely to survive and grow in various competitive environments and to explore the implications of projected performance measures for firms in the industry and for farmers. The focus of this research is on the economic consequences of pricing decisions made by subjects in the gaming experiments. The means and standard deviations of price decisions made by managers from different types of organizations and under different competitive environments imposed in the Babb and Bohl experiments are the basic inputs for the simulator used in this research. The simulator provides longer run implications of repeated price decisions observed in the gaming experiment.

Procedures

The management game used for experimental gaming was redesigned as a simulator (Babb and Bohl 1969a, b). Since the focus was on the eighteen price decisions in the original experiment (prices for feeds, fertilizers, grains, and services), decision rules were developed to handle the twenty-three nonprice decisions. These decision rules were applied uniformly in our analyses, which had the effect of holding nonprice decisions constant. The simulator was made stochastic by incorporating a random number generator to develop price distributions for repeated trials, given the means and standard deviations of prices in the gaming experiment. Procedures were incorporated in the simulator so that random walk experiments could be performed.

Experiments were performed with the simulator using two treatment effects, type of organization and degree of price competition. Subjects from experimental gaming were classified into seven categories based on size, type of ownership, and number of retail outlets as follows: (*a*) independent proprietorship with single retail outlet and annual sales less than $600,000, (*b*) independent proprietorship with single retail outlet and annual sales of $600,000 to $1,400,000, (*c*) independent proprietorship with single retail outlet and annual sales over $1,400,000, (*d*) independent proprietorship with multiple retail outlets and annual sales over $1,000,000, (*e*) cooperative with multiple retail outlets and annual sales of $700,000 to $2,500,000, (*f*) cooperative with multiple retail outlets and annual sales over $2,500,000, and (*g*) cooperative with single retail outlet and annual sales of $1,000,000 to $3,500,000. The hypothesis to be tested was that projected performance would be the same for managers from the seven types of organizations.

In the experimental gaming study, Babb and Bohl set the cost of goods sold and the average price of products sold by subjects' competitors, i.e., the researchers acted as competitors so that all subjects faced the same competitive environment during a particular decision period. Three levels of price competition were imposed by Babb and Bohl representing situations of low, normal, and high gross margins. These margin levels were used in experiments with the simulator. The hypothesis to be tested was that projected performance would be the same under different competitive environments.

Experiments were conducted with the simulator where a replication refers to a one-year decision period under the specified combination of treatments. The first type of experiment involved fifty independent replications for managers from seven types of organizations under normal margins, under low margins, under high margins, and under the combination of margin situations used in the prior study.[1] The second type of experiment used fifty independent replications of the three to five most

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[1] The sample size of fifty was selected prior to conducting experiments with the simulator on the basis of standard deviations from the previous research, a confidence interval of 95%, and desired interval lengths. Subjects in the previous research made six sets of decisions in sequence. For each set of decisions, they faced various combinations of low, normal, or high margins that were balanced over the sequence of six decision periods; that is, subjects did not face low margins for all products in the game during one decision period. The simulation experiment that refers to the combination of margins used in the previous study duplicated the combinations used earlier.

Table 1. Performance Results and Statistical Tests for Seven Types of Farm Supply Organizations under Conditions of Normal Margins

Performance Variables	Average Performance by Type of Organization[a] (a)	(b)	(c)	(d)	(e)	(f)	(g)	ANOV F-Value[b]	Student-Newman-Keuls Ranking[c]
Return on investment (%)	4.36	3.78	5.59	5.16	5.00	4.08	5.62	17.0	7 3 4 5 1 6 2
Profit as % of sales	1.41	1.17	1.71	1.71	1.57	1.22	1.75	19.3	7 3 4 5 1 6 2
Profit ($)	22,640	19,660	29,235	26,787	26,073	21,372	29,418	16.5	7 3 4 5 1 6 2
Total sales ($1,000)	1,621	1,689	1,713	1,570	1,669	1,752	1,684	10.0	6 3 2 7 5 1 4
Gross margin feed (%)	16.22	16.11	16.50	16.80	16.77	16.23	16.93	22.6	7 4 5 3 6 1 2
Gross margin fertilizer (%)	14.97	15.23	15.52	15.91	15.82	15.36	15.57	12.0	4 5 7 3 6 2 1
Gross margin grain (%)	2.96	2.72	2.75	2.96	2.69	2.59	2.73	7.6	1 4 3 7 2 5 6
Operating expenses as % of sales	12.34	11.75	11.57	11.77	11.45	11.48	11.50	10.5	1 4 2 3 7 6 5

[a] Types of organizations are identified as (a) through (g) as in text.
[b] All differences among group means significantly different at the 0.01 level of probability.
[c] Lines below the ranks of types of organization indicate that the means for these types are not significantly different at the 5% level of probability.

viable types of organizations under normal margins.[2] The third type of experiment involved twenty independent replications of a random walk situation covering ten decision periods by all seven types of organizations and by the most viable types of organizations, under normal margins.[3]

The performance variables (simulator output) used in subsequent statistical analyses included return on investment, profit, profit as a percent of sales, total sales, operating expenses as a percentage of sales, and gross margins for feed, fertilizer, and grain merchandizing. A one- or two-way analysis of variance (ANOV) was used to analyze performance variables, depending upon the design of the specific experiment. If the ANOV revealed significant differences[4] in performance variables among types of organizations, the Student-Newman-Keuls multiple range test was used to rank these categories.

[2] The selection of the three to five most viable types of organizations was based on the criteria of highest profits and returns on investment in simulation experiments, which included all classes of organizations.

[3] For the random walk experiments, the starting prices were based on the average of prices established by managers from each of the seven types of organizations in the previous research. Cost of goods sold was held constant throughout the random walk. Given the standard deviations from the previous study, the random number generator created the distribution of prices for that period. Prices for the second year were based on averages of prices in the first, and the random number generator then created prices for the second year and so on through ten periods. Thus, prices for different products could drift up or down over time.

Results

The first three experiments included all types of organizations under low, normal, and high margin environments. Differences in all performance variables among types of organizations were highly significant in each of the three experiments (table 1).[5]

[4] The F-value was significant at the 5% level of probability.

[5] Results for only the experiment using normal margins is in-

Table 2. Analysis of Variance Results for Performance Variables Using Two Treatments

Performance Variable	ANOV F-Values: Competitive Environment Effect*	Organizational Effect*	Interaction Effect
Return on investment	174	92	1.45
Profit as % of sales	154	107	1.34
Profit	176	90	1.31
Total sales	96	53	1.16
Operating expenses as % of sales	528	71	1.10

* Differences among group means for all performance variables were significantly different at the 0.01 level of probability.

In general, firms in organizational classes *c*, *d*, *e*, and *g* were most profitable and had the highest gross margins for feeds and fertilizers. This was largely due to cooperative organizations taking a lower margin on grain and higher margins on feed and fertilizer, compared to proprietary organizations. Firms in organization classes *a* and *b* generally had higher expenses as a percentage of sales, which partly accounted for their lower profitability. The most profitable groups did not necessarily experience the highest sales. From an economic standpoint, the results show important differences among types of organizations with respect to profitability measures. Differences of 1% to 2% in return on investment over time may affect survival.

The particular combinations of margin levels used for the six decision periods in the previous research were used as input to the simulator to obtain response surfaces for both types of organization and competitive environment. Both of these factors were highly significant (table 2). The interaction term for these factors was not significant, indicating that the relative performance of managers from different types of organizations was stable among different competitive environments. Ordinal rankings of types of organization on the basis of performance variables were essentially the same as in the experiments with low, normal, and high margins. This indicates consistency in performance among types of organization with variation in level of margins and with combinations of margin levels.

On the basis of the previous experiments, organizational classes *c*, *d*, *e*, and *g* were selected as the most viable, and the experiment with normal margins was repeated using only these four groups. There were still significant differences in performance variables among these four groups, but most of the rankings were not in completely separated groups (means that were the basis for ranking were not significantly different) as in the earlier experiments (table 3). Furthermore, the economic impact of differences in performance among these four types of organization is probably not important in terms of their relative success or survival.

The ten-period random walk experiment for all types of organizations under an environment of normal margins was replicated twenty times. Because of autocorrelation in performance measures among the ten time periods, ending net worth (sum of profits over ten periods) for each of the twenty trials was used as the performance variable. There were significant differences in ending net worth among types of organizations, and the same types of organizations (*c*, *d*, *e*, and *g*) that were most profitable in earlier experiments had the highest net worth. There was a tendency for prices to decline during the ten-period random walk as a number of managers in the previous study adopted a policy of pricing slightly below their competitors. This behavior was reflected in the results of the simulator. The ending net worths of the four most viable types of organizations were not significantly different in the experiment including only those groups.

cluded, as the results for high and low margins show an identical pattern. Of course, the level of profitability was higher or lower in these situations compared to normal margins.

Conclusions and Implications

The null hypothesis that performance would be the same for managers from the seven types of organizations was rejected in all experiments for all mea-

Table 3. Performance Results and Statistical Tests for the Four "Most Viable" Types of Farm Supply Organizations under Conditions of Normal Margins

Performance Variables	Average Performance by Type of Organization[a]				ANOV *F*-Value	Student-Newman-Keuls Ranking[b]
	(*c*)	(*d*)	(*e*)	(*g*)		
Return on investment (%)	5.58	5.44	5.50	5.96	2.9*	7 3 5 4
Profit as % of sales	1.69	1.78	1.68	1.84	3.1*	7 4 3 5
Profit ($)	29,227	28,355	28,839	31,309	3.2*	7 3 5 4
Total sales ($1,000)	1,733	1,599	1,721	1,708	19.6**	3 5 7 4
Gross margin feed (%)	16.61	16.85	16.95	16.81	4.3**	5 4 7 3
Gross margin fertilizer (%)	15.35	15.86	15.67	15.67	5.5**	4 7 5 3
Gross margin grain (%)	2.72	2.94	2.65	2.74	7.6**	4 7 3 5
Operating expenses as % of sales	11.59	11.80	11.35	11.58	5.2**	4 3 7 5

[a] Types of organizations (*c*), (*d*), (*e*), and (*g*) are identified in text.
[b] Lines below the ranks of types of organization indicate that the means for these types are not significantly different at the 5% level of probability.
* Differences among group means significantly different at the 0.05 level of probability.
** Differences among group means significantly different at the 0.01 level of probability.

sures of performance. The experiment using combinations of margins was the basis for rejecting the null hypothesis that performance would be the same under different competitive environments. This was further supported by important differences in performance among the experiments with low, normal, and high margin levels. The null hypothesis that performance would be the same for the three to five most viable types of organizations was rejected, but the economic importance of these differences is probably not important to their survival. In fact, there were no significant differences in the ending net worth of the most viable groups in the random walk experiment.

If the types of organizations identified as the most viable in this research are the ones that survive and grow, the future organization and structure of farm supply retail outlets will change.[6] The current balance of firms by types of ownership is not projected to change, as two of the most viable groups were cooperative and two were proprietary. But types of organizations projected as the most viable had either large single retail outlets or had medium- or large-size multiple retail outlets. This implies that retail outlets in the industry will become more concentrated over time. The results are consistent with the rapid decline in the number of smaller firms that is taking place. The results do not imply the complete disappearance of firms in a particular type of organization. There was at least one firm in the poorest performing group that performed at least as well as the average performance in the most viable group.

Part of the poor performance of smaller firms could be attributed to their lack of control over operating expenses. Beyond this, managers from the smaller firms did not understand how their customers responded to price differences and the impact of prices established by competitors. They thus established inappropriate price policies in the gaming experiment. Educational efforts with smaller firms may improve their performance and viability.

Fewer and larger firms will increase the distance farmers travel to purchase inputs and to market grain. Farmers may pay higher prices for purchased inputs. In the case of feeds and fertilizers, firms in the most viable group charged higher prices, but there was an erosion of prices even among these firms in the random walk experiment. Furthermore, in the real world, there may be economies of size for the larger firms or those with multiple retail outlets that were not built into the simulator, and this could temper some of their higher prices. Differences in prices of feeds, fertilizers, and grains among different types of organizations suggest that it is advisable for farmers to compare prices.

In general, the decisions made by managers did not generate returns on investment that would attract large amounts of capital to the industry. Improved decisionmaking may be necessary to attract capital if industry expansion or renovation is needed.

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[6] The likelihood of such a change is reinforced by the fact that the previous research did not detect significant differences between the behavior of managers in a laboratory setting and in real life.

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Returns to Information: An Addendum

David L. Debertin, Robert J. Rades, and Gerald A. Harrison

A 1975 *Journal* paper by the authors (Debertin et al.) utilized a computerized management game to measure the returns to information for Indiana corn and soybean producers. Results indicated a rather substantial return to information. However, estimates in the paper have been questioned by agricultural economists at Purdue, the University of Kentucky, and elsewhere because participants in the laboratory experiment were students, not experienced farmers. In response to these criticisms, a second experiment was conducted using experienced farmers as participants. The identical management game (Debertin, Harrison, and Rades) and a similar experimental design were used in both experiments.

Farmer Participants

Participants in the laboratory experiment consisted of thirty-nine farmers from six central Indiana counties. Farmers in the experiment represented a substantial diversity in age, education, and size of commercial operation (table 1). An honorarium of $50 was paid to each farmer participating in the experiment. In addition, prizes of $25, $15, and $10 were given to the three farmers generating the most profits in each group.

The high cost of the experiment (approximately $100 per participant) made it necessary to limit the sample size to approximately forty participants. Results from the earlier study revealed a great deal of within-group variability in the profit performance of participants. Hence, it was decided to divide the farmer participants into only two groups. All participants in this experiment were provided with feedback from the previous decision(s).

Each farmer made a predecision prior to the main experiment. The predecision ensured that the farmers were familiar with the gaming procedures and served as the basis for assignment of farmers to the two treatment groups (with and without research information). Farmers were ranked according to predecision profits and assigned to the treatment groups following the same procedure used in the earlier study with the students (Debertin et al.).

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Table 1. Characteristics of Farmer Participants

Characteristics	Mean	Range
Age (years)	41	21–60
Education (years)	12.6[a]	10–16
Total acres farmed	806[b]	250–1800
Total acres corn	440	75–1200
Total acres soybeans	217	0–850
Days worked off farm	8.5	0–90

[a] Students participating in the earlier experiment had a mean educational level of 15.6 years with a range of from 13.5 to 18 years.
[b] Most of the students participating in the earlier experiment came from farms throughout Indiana. A few came from states such as Illinois and Ohio. Students' farms averaged 449 acres and ranged in size from 0 to 1,640 acres. Only five students were not reared on farms. Approximately 90.4% of the students had been involved in corn or soybean production.

Statistical Results

Mean profits generated per year for the two groups of farmers over the five years of game operation are presented in table 2. The earlier data from the experiment with the students is also presented for comparison. The data in table 2 reveal that the farmers did not do as well at managing the simulated farm as the students. Farmers without information averaged $8,672 net returns per year over the five decision periods (years), and students without information averaged $11,935 net returns per year over the five decision periods, a difference of $3,263. Farmers with information averaged $9,724, while students with information averaged $15,866, a difference of $6,142. Moreover, the return to information for the students was $3,931 per decision period, while for the farmers the return to information was $1,052.

A two-way analysis of variance of the data is presented in table 3. Information had a significant positive impact on profit levels in three of the five decision periods. Students were able to generate significantly greater profits with the game than were farmers in four of the five decision periods. A significant F-ratio on the interaction effect would suggest that students with information were better able to decode and use information in a decision-making context than were farmers (Welch). How-

Table 2. A Comparison of Profits Generated with the Game for Students and Farmers

Year (Decision Period)	Farm Management Students: Without Research Information $n = 17$	Farm Management Students: With Research Information $n = 16$	Experienced Farmers: Without Research Information $n = 20$	Experienced Farmers: With Research Information $n = 19$
1	−2,292	−504	−2,746	−3,897
2	14,094	19,316	9,801	12,507
3	17,787	25,267	12,482	14,909
4	4,099	7,177	−152	1,583
5	25,990	28,073	23,977	23,519
Average of 5 years	11,935	15,866	8,672	9,724

ever, the interaction effect was significant in only one of the five decision periods. Hence, it is apparent that information has a significant impact on profit levels generated with the game. Students were able to generate significantly larger profits with the game than were farmers.

Differences in the Behavior of Farmers and Students

Why did the farmers perform differently than the students? One explanation for the observed differences in profit levels between students and farmers is that these differences may reflect marginal returns to an education in a college of agriculture. The "no-information" students may have been exposed to information useful in making game decisions in formal course work prior to the time the experiment was run.

A second, perhaps more troublesome, explanation is that the students, having worked for nearly four years under academic pressures of a university environment, adapted more readily to the abstractions of the simulated (laboratory) environment than did the experienced farmers. This line of reasoning would seem to suggest that the students were not in fact better farm managers but rather were merely better able to play the game.

A third explanation for observed differences in the performance of the farmers and the students is that the information (given to some of the participants and used as a basis for deriving coefficients and relationships within the game) may not be a correct mirror of the real world. Students may accept the information at face value. The farmers may be conditioned to believe that not all information (even that put out by university colleges of agriculture) is correct. Farmers may indeed be superior to students in finding errors in research and extension information.

A major research effort now needs to be directed toward an analysis of the extent to which the behavior of participants in computerized gaming ex-

Table 3. Analysis of Variance of Profits for Students and Farmers

Decision	Condition	F-Ratio	Significance
1	Information—No Information	0.02	Nonsignificant
1	Students—Farmers	1.59	Nonsignificant
1	Interaction	0.97	Nonsignificant
2	Information—No Information	5.94	0.01
2	Students—Farmers	12.06	0.005
2	Interaction	0.63	Nonsignificant
3	Information—No Information	10.57	0.005
3	Students—Farmers	28.07	0.005
3	Interaction	2.98	0.05
4	Information—No Information	2.23	0.10
4	Students—Farmers	9.66	0.005
4	Interaction	0.18	Nonsignificant
5	Information—No Information	0.18	Nonsignificant
5	Students—Farmers	3.74	0.05
5	Interaction	0.57	Nonsignificant
Total	Information—No Information	4.50	0.025
Total	Students—Farmers	17.28	0.005
Total	Interaction	1.65	Nonsignificant

Note: The model was $Y_i = \alpha_i + \beta_1 D_{1i} + \beta_2 D_{2i} + \beta_3 D_{1i} D_{2i} + \epsilon_i$, where Y_i = mean profits for the ith participant, $D_{1i} = 1$ if participant was a student (0 otherwise), $D_{2i} = 1$ if participant received information (0 otherwise), and $\epsilon_i \sim N(0, \sigma^2)$.

periments is consistent with the behavior of farm managers in the real world. Such an experiment might focus not only on the managerial decisions farmers make under controlled laboratory conditions utilizing a management game but also on the managerial decisions the farmers actually make in the real world. A greater degree of experimental realism would be obtained by incorporating additional managerial decisions dealing with other aspects of crop production. Intensive questioning prior to the laboratory experiment would enable researchers to determine the actual decision made by the farmer with regard to key managerial practices in crop production. These data would then be compared with data subsequently gathered within the laboratory experiment.

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A Note on the Social Returns to Private Research and Development

Willis L. Peterson

The seminal work of Schultz and Griliches (1958, 1964), along with more recent efforts by Ayer and Schuh, Evenson (1967, 1974), Peterson (1967, 1971), Schmitz and Seckler, and others, have shown that investment in agricultural research has yielded a high social return. Although private investment in agriculturally related research and development (R&D) has been taken into account in many of these studies by adding rough estimates of private research to the public expenditures, there is virtually no independent information on the social returns of private R&D relating to agriculture. (This is probably due to a lack of data on private R&D.) It is certain that the expected private rate of return to this investment is at least as great as the expected private rate of return to alternative investments, else it would not be carried out. But is the social return to private R&D high enough to justify this investment from society's point of view?

I shall argue in this note that in spite of the lack of empirical evidence on the social returns to private R&D, we can be assured that, as long as R&D is privately profitable, it is also socially profitable. The key to the argument is the excess of social over private returns. This is not to say that private investment decisions will result in a socially optimum level of R&D, particularly basic research. It is recognized that because of the "public goods" nature of the information generated by basic research, most of this work has to be publicly funded. As Nelson points out, "the fact that industry laboratories do basic research at all is itself evidence that we should increase our expenditure on basic research" (p. 304). Hirshleifer takes a somewhat different view, arguing that there may be overinvestment in private information-gathering activities if the information remains private "in the sense of being purely redistributive, not leading to any improvement in productive arrangements" (p. 573). However, in the case of the farm-supply industry, it will now be argued that private R&D yields a private return only if it results in an "improvement in productive arrangements," i.e., yields a social return by increasing agricultural output.

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Private and Social Returns Defined

It will be useful at the outset to define the meaning of "private" and "social" returns as they relate to private R&D. Private returns are defined as the additional net earnings that the firm is able to capture by investing in R&D. Additional net earnings in this case are defined as the additional sales that result from R&D minus associated production and marketing costs that may be required to produce and market the products or services that result from R&D. Of course, the associated costs do not include the R&D expenditures. In the context of cash flow analysis, the R&D costs are the cash outflows, while the additional net earnings (added gross sales minus associated costs) represent the net cash inflows.

Investment in R&D is profitable for the firm if the discounted present value of the stream of added net earnings is equal to or greater than the accumulated R&D expenditures using the appropriate discount rate, such as the rate of interest on borrowed funds or the opportunity cost of capital on equity funds. This is not to say that all private R&D turns out to be profitable. No doubt all firms that conduct R&D have invested in projects that have turned out to be unprofitable. Indeed, it is quite possible that during a specific period the entire R&D effort of certain firms have turned out to be unprofitable (Mansfield). In this sense, R&D is no different than any other investment. No one can be certain of the payoff until the returns have come in. Over the long run, however, the profitable projects must more than offset the unprofitable ones, else the firm will discontinue R&D or go out of business entirely.

In measuring the rate of return to public research, the social returns have been defined as the value of additional output that is forthcoming because of the research. Traditionally, the social returns have been measured as the change in consumer surplus or area between the old and new supply curves bounded on the top (or right) by the demand curve (Griliches 1958, Peterson 1967). It would seem logical to define the social returns to private R&D in the same manner. Therefore, let us define the social returns to private R&D as the value of additional agricultural output that is forthcoming because of the R&D, as measured by this area of consumer surplus.

Why Social Returns Exceed Private Returns

In order for farmers to adopt new or improved inputs made possible by private R&D, the value of marginal product (VMP) of the inputs in terms of agricultural output must be greater than their respective prices. In other words, the adoption of new inputs must reduce production costs from what they would otherwise be. If not, farmers would continue to use the old inputs or technology. The prices of new inputs must include not only a return to the R&D that made possible the production of the inputs but also a recoupment of R&D costs that did not result in a saleable product.[1] This is the only way private firms can capture a return to their R&D. Input prices must exceed their pure production costs by at least enough to provide a normal return on the investment in R&D, otherwise the R&D will not be done.

As farmers adopt the new, more productive inputs and unit costs begin to decline, the supply curve of agricultural products shifts to the right as illustrated by the shift in supply from S_0 to S_1 in figure 1. It is this shift in the supply curve that gives rise to the conventional measure of consumer surplus or social returns represented by the single line shaded area in figure 1.

It is important to recognize, however, that the reduction in production costs to farmers and the resulting shift in supply from S_0 to S_1 does not reflect the full increase in output that has resulted from the R&D. Part of the increase in output, marginal physical product (MPP), stemming from the use of new, more productive inputs is covered up by that part of the price increase that represents a private return to private R&D. Thus, the shift in supply as measured by the reduction in production costs understates the full contribution of private R&D to output.

A simple numerical example illustrates the point. Consider one variable input whose MPP (at a given quantity) doubles because of R&D. Assume the price of the input rises by 50% but half of the price increase is a return on the R&D that made the increase in MPP of the input possible. The percentage decrease in marginal cost (shift in the supply curve) is 25% when the private return to the R&D is included in the price. But the shift in supply would be 37.5% if the input price did not contain a private return to the R&D. The example is summarized in table 1.

To treat private R&D the same as public research from the standpoint of measuring social returns, then that part of the contribution of private R&D that reimburses the private firms for the cost of the R&D should be included, shown by the double-line shaded area in figure 1. Hence, the relevant supply curve is S_2 in figure 1, and the area of

[1] Part of these R&D costs may be failures and part the nondirected or "basic" research conducted by the firm.

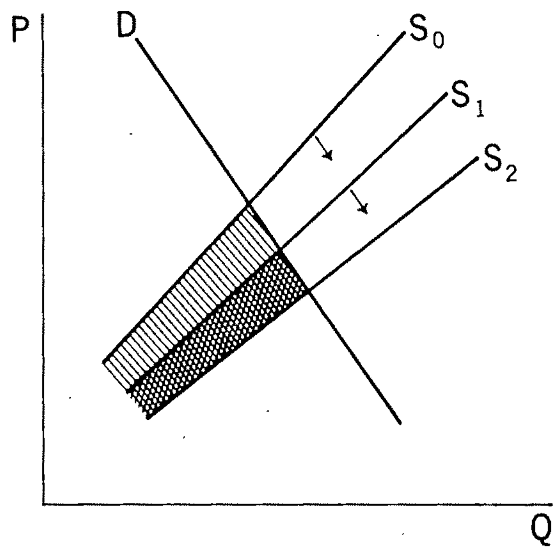

Figure 1. Social returns to private R&D

consumer surplus should include both the single- and double-line shaded areas. In terms of the above example, the relevant supply curve would be that which exhibited a 37.5% shift rather than the 25% change.

If the consumer surplus represented by the double-line shaded area in figure 1 is neglected, it amounts to double counting the cost of private R&D when assessing the social rate of return to this investment. The cost would be included once on the cash outflow side and would appear again on the return side as a reduction in cash inflow (social returns). Such a procedure would be comparable to subtracting the cost of public research from its returns before matching its costs against returns in order to compute a benefit-cost ratio or internal rate of return. Of course, this procedure is not done in evaluating the profitability of any investment.

Because the private returns to private R&D are included within and are a subset of the social returns, for society as a whole the social returns to private R&D must be greater than the private returns.[2] Unless the marginal cost of producing the output using the improved input is lower than the

[2] Externalities aside. However, it is not evident that externalities are more prevalent in private than public R&D.

Table 1. Illustrating the Effect of R&D on Marginal Cost (MC)

	MPP	Input price	MC	% ΔMC
Initial situation	100	$100	$1.00	—
Price includes R&D cost	200	150	0.75	−25
Price excludes R&D cost	200	125	0.625	−37.5

marginal cost of production using the traditional input, the new input will not be adopted, and there will be no private or social returns. In other words, in order for there to be private returns, the total area between S_0 and S_2 in figure 1 must be greater than the area between S_1 and S_2. Otherwise, there will be no incentive for farmers to adopt the input.

This same reasoning applies to the case where R&D reduces the cost of producing an input of constant quality, e.g., nitrogen fertilizer. Even though the price of the input is reduced because of R&D, the price still must include a return to the R&D in question. Hence, the observed shift in supply of agricultural products that occurs because of the reduction in costs understates the full contribution of the R&D to output.

Although the private returns to R&D are smaller than the total social returns, the ratio of private to social returns can be expected to vary between inputs and between points in time. A new input that does not have close substitutes and therefore exhibits a relatively inelastic demand (facing the supplier) should yield higher pure profits and a higher private relative to social return, other things being equal. However, over the long run, as more and closer substitutes become available and pure profits are eroded away, the private returns should diminish relative to the social returns. Also, the ratio will depend on the point in time (relative to the introduction of the input) the returns are evaluated. The more time that has elapsed and the greater the number of substitutes that become available, the lower should be the private relative to total social returns. Indeed, after a long period of time has elapsed, it is not unreasonable to believe that the annual private returns to many innovations become negligible, while their social returns continue on indefinitely. Such is the nature of economic growth.

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A Brief Assessment of Extension Land Use Educational Publications

Craig L. Infanger and A. Frank Bordeaux, Jr.

Land use policy is once again a focus of attention for many agricultural economists. Extension educational programs in this area have produced a large number and variety of publications related to land use. A request for available printed materials on this subject was sent to the fifty extension directors by the authors. The purpose of this paper is to briefly review these publications, assess the strengths and weaknesses of the literature, and offer brief constructive criticism.[1]

This review of extension's land use publications is appropriate for three reasons: (*a*) printed media are an important channel of communications between extension professionals and their clientele, and every effort to upgrade and improve publications should be made; (*b*) cross-fertilization between extension programs improves the total educational effort; and (*c*) exchange of publications is an important method of communication among extension professionals, and this article hopes to foster this communication.

Extension's Land Use Educational Publications

Forty-one extension directors responded to a request for available printed materials in land use. Four of these states—Tennessee, Georgia, Maryland, and Massachusetts—had publications in process at that time. Materials supplied by six states—Arizona, Hawaii, Nevada, New Mexico, Rhode Island, and Wisconsin—were not considered educational publications in the same sense as the remaining materials.[2] Subject matter is the only common characteristic of the publications from the remaining thirty-two responding states. The diversity in format and content is remarkable. However, three approaches seemed to be used most often.

North Carolina's educational "package," *Land Use Planning in North Carolina*, illustrates the package approach and consists of a coordinated series of pamphlets on land use.[3] Another "package" of eight topically coordinated pamphlets is available from Texas and is unique in the sense that it provides in the first pamphlet a historical perspective for the development of land use patterns in the state. Wyoming also uses a "package" format to produce *Series Six*, a set of six very brief (two-page) treatments of related aspects of land use and community planning.

Several states provide land use planning information in extension bulletin or circular form. One of the most comprehensive of these is *Using Comprehensive Planning in Montana* (House). Other bulletins include *A Guide for County Land Use Planning: Colorado* (Davis and Sorensen), *Some Legal Aspects of Land Use Planning in the Mountain State* (Zagaris), and *Performance Standards: A Technique for Controlling Land Use* (Stockham).

Only one state uses the case study approach to land use education publications. Illinois has an educational package, *Illiville, Illinois: Planning Documents*, which consists of (hypothetical) annual reports from a city and a planning commission, a review of state laws, long-range plans, zoning ordinances, subdivision controls, and other related materials (Illinois Bureau of Community Planning). A modified case study approach was used in one publication coming out of Utah, *Workbook in Land Use Planning* (Germanow and Grimsely).

The remaining publications can be classified as potpourri. Various issues of several newsletters including *Trade Secrets*, (Mississippi Cooperative Extension Service), *Palmetto Economics* (Clemson Cooperative Extension Service), and *Kentucky Economics Topics* (Kentucky Cooperative Extension Service) have devoted issues to land use. In many cases, these newsletters appear to have become integral parts of educational programs. Numerous other types of publications address some specific subset of the land use issue in some detail. Examples of this are *Open Space Taxation* (Barron and Florea), *Transfer of Development Rights* (Chavooshian and Norman), and *Conservation Easements* (Liden).

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The authors wish to acknowledge the helpful suggestions and criticisms of Verne W. House, Leon E. Danielson, and the *Journal* editors and reviewers.

[1] Doubtless, we did not receive all the available printed materials. This is unfortunate but unavoidable because a few directors did not respond and others may have failed to forward all available publications. Although several omissions were detected by the authors, others may remain. In addition, the authors recognize that extension economists rely on information sources other than printed materials. However, these are beyond the purview of this article as are the research bulletins, seminar proceedings, and journal articles.

[2] Included in this group were publications on selecting home sites, research bulletins on land taxation, bibliographies, conference proceedings, and related state government documents.

[3] The North Carolina package has been adapted in whole or in part for use in Arkansas and South Dakota.

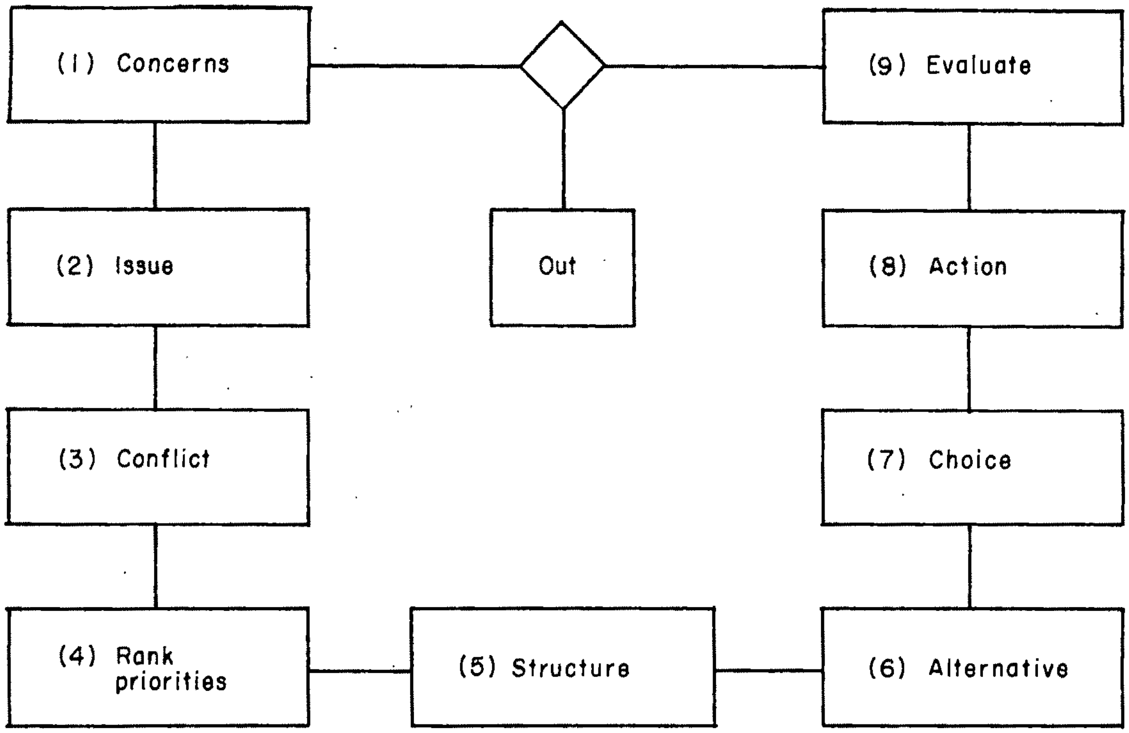

Figure 1. Issue cycle flow chart. Source: Gratto.

A Brief Assessment

Charles Gratto has developed a general framework that integrates the main features of the public affairs education process. The Gratto issue-cycle flow diagram is shown in figure 1. Participants in the resolution of a public issue such as land use planning generally begin at some point of concern (1). The search for resolution generates discussion that gives the issue (2) a name and defines it in action terms. Interests conflict (3), and debate is generated over priorities for resource allocations. The debate forces a ranking of priorities (4), and more objective and scientific knowledge defines the issue in more realistic terms. The structure (5) of the problem can be seen more clearly, although objective views of the issue do not converge. Policy alternatives (6) are defined, and participants evaluate each in terms of complex social and economic dimensions. Some public choice (7) is forthcoming, which is followed by action (8), implying either change or continuation of status quo. Finally, a period of evaluation (9) follows in which consequences and effects of the action are weighed. If the action generates "satisfaction," the cycle recedes; "dissatisfaction" causes the cycle to resume.

Intervention of public affairs education can occur at any point (cell). In terms of the land use issues, awareness education programs include information (publications) illustrating and defining the land use issue and outlining the historical perspective for the current controversy (cells 1, 2, and 3). Policy alternatives education programs provide information (publications) on the planning process, present land use control techniques, present federal and state legislation, and proposed new control techniques (cells 4, 5, and 6). Finally, consequence evaluation education programs focus on citizen involvement in public choice, effectiveness of land use controls, and implications of land use planning for various interest groups (cells 7, 8, and 9).

Classifications of Extension Publications

The various states' publications were classified into at least one of the educational categories (table 1).[4] Because educational intervention can come at any point in the issue cycle, it was not expected that every state would have materials in every category. It should, however, be reasonable to assume that for all states publications are available in some form for all categories.

Thirteen states have materials appropriate for intervention in the awareness phase of the issue

[4] The authors recognize there are numerous possible classification schemes and made the choice to utilize the Gratto framework. Also, it is recognized that the subject matter coverage of several of the publications extends over one or more categories. However, inclusion in only one category is based on the primary focus of the publication.

Table 1. Extension Land Use Education Publications by State and Area of Emphasis

Awareness Education	Policy Alternatives Education	Consequence Evaluation Education
(1) Problem Situation and Perspective Alabama, Arkansas, Iowa, Kentucky, Michigan, Minnesota, Mississippi, Montana, New Hampshire, North Carolina, Texas, Wyoming.	(1) Local Planning Process Agencies, Functions Alabama, Arizona, Arkansas, Colorado, Illinois, Kentucky, Michigan, Mississippi, Montana, New York, North Carolina, North Dakota, Oregon Pennsylvania, South Dakota, Texas, Utah, Vermont, Wyoming.	(1) Citizen Involvement in Public Choice Arkansas, Kentucky, Missouri, North Carolina, Oregon, Texas.
(2) Historical Perspective Texas.	(2) Present Land Use Controls Arkansas, Delaware, Florida, Illinois, Kentucky, Montana, Nebraska, New Hampshire, North Carolina, North Dakota, South Carolina, Vermont, Virginia, West Virginia, Washington, Wyoming.	(2) Effectiveness of Land Use Controls Missouri, Montana, Washington.
	(3) Federal and State Legislation Arkansas, Colorado, Illinois, Kentucky, Mississippi, Nebraska, North Carolina, Pennsylvania, South Dakota, Texas, Vermont, West Virginia, Wyoming.	(3) Implications of Land Use Planning North Carolina, Wyoming.
	(4) Proposed New Planning and Control Techniques Alabama, Connecticut, Mississippi, Montana, New Jersey, North Carolina, Oregon, West Virginia.	

cycle.[5] One of the best of these publications is "Planning for Tomorrow's Communities" (North Carolina Agricultural Extension Service). The text begins with the warning: "The landscape around us has taken on new and controversial aspects under pressures from technological and social changes" (p. 1). Pursuing that theme, the land use policy issue is outlined for North Carolinians in terms of population growth, employment, land use patterns, and the planning and choices ahead. This type of information can assist people in defining more precisely their concerns about use and development of land resources.

While there are good examples of awareness-type publications that outline the problem and give some perspective, there is a paucity of information on historical development. Texas is the only state with a publication that traces the development of the present state land use pattern (Texas Agricultural Extension Service).

In the second phase of the issue cycle, the policy-alternatives educational effort, publications are abundant. Nineteen states have publications on the functioning of local planning agencies. Many of these provide a step-by-step explanation of the comprehensive planning and land use regulation process. For small group education, the Utah *Workbook in Land Use Planning* (Germanow and Grimsley) seems to be a particularly appealing document for use in this area.

Publications related to present control techniques are plentiful. The Wyoming *Series Six* covers zoning in two pages under the title, "Don't Talk to Me About Zoning." South Carolina has extensive and detailed examinations of both zoning law and subdivision control—a total of ninety-two pages (McLemore, Ledbetter). Between these extremes are numerous publications differing widely in emphasis and format.

Most of the print is devoted, justifiably we think, to the police power techniques of control—zoning, subdivision regulation, and building codes. Without much question these are the most familiar of land use controls. If there are important weaknesses in the coverage of zoning, we see these as standing out. First, there is virtually no mention of the

[5] The Extension Committee on Policy (ECOP) of the Extension Service has recently published some land use materials, *Land Resources Today*, of which pamphlet No. 1 addresses the problems, situation, and perspectives (USDA).

Model Land Development Code of the American Law Institute. This is intended as a replacement for the current state enabling legislation and could go a long way to improve inadequacies in local planning and zoning. Second, we do not think sufficient attention has been devoted to the political-legal problems of planning and zoning. A few pointers from Richard Babcock's *The Zoning Game* might prove useful in some publications.

On land use controls other than zoning, the available material is sparse. The state of Washington has a pamphlet on open space taxation (Barron and Florea). However, no treatment has been given to the "takings" issue, the use of public expenditures to control land use, or nonzoning (i.e., deed restrictions, covenants).

Several states have publications on state land use laws. The University of Arkansas, for instance, has published two "Guidelines" outlining statutory requirements for municipal and county planning, *Guidelines for County Planning in Arkansas* and *Guidelines for Municipal Planning in Arkansas*. Only a few states have published information on proposed federal land use legislation, mostly in newsletter form.

Policy alternatives are probably the most important segment of the second phase of the issue cycle. Yet, only eight states have publications that address one or more of proposed new land use controls. The work of most notoriety is New Jersey's "Transfer of Development Rights: A New Concept in Land Use Management" (Chavooshian and Norman). Transfer of development rights (TDR) is a modification of zoning law intending to facilitate markets for development rights to land. It is one of several alternatives to be put before clientele groups. One Oregon publication reviews some of the newer techniques for land use control (Pease and Stockham). Topics included in this publication are performance zoning, TDR's, conservation easements, windfall gains taxes, and public purchase-leaseback.

The third phase of the issue cycle, consequence evaluation education, is an area of increasing importance. Many states are initiating new land use controls. Extension should be actively engaged in providing feedback on the consequences and impacts of these new programs. The paucity of publications in this area suggests we may be doing otherwise.

With respect to citizen involvement in public choice about land, only six states have any publications in this area. None of these are evaluative in any sense. Some explain who is involved in the planning process and at what points citizen input is possible (desired?).

Very little critical evaluation of land use control effectiveness is available. Information on taxation is plentiful enough to provide the basis for a fair evaluation of taxation as a land use control. But what about zoning? purchase of development rights? conservation easements?

Implications of land use controls for agriculture and other groups is another topic addressed in weak fashion—brief mention is made in the North Carolina and Wyoming literature. No one has come forward to illustrate the trade-offs faced by farmers in the choice between preservation or nonpreservation of agricultural land. Similarly, there is little information about the shifting of property tax burdens under preferential assessment of farmland. These and other implications are important in matters of public choice.

Some Observations

From this review of extension land use educational publications, the following observations (challenges?) are offered. (*a*) The publications from many states seem to be a response to an immediate pressing land use problem. An example is *The North Dakota Farmer/Rancher Looks at Severed Mineral Rights* (Johnson, Beck, and Sillers), published in response to the increased activity in coal strip-mining. This type of immediate reaction is appropriate and positive but does not seem to be followed by or coordinated with systematic development of a "package" of materials useful among different clientele groups and over extended time periods. This would explain in part the reason why the greater numbers of publications are in the policy alternatives category rather than awareness education. This raises the question of whether or not there exists enough commonality between states and land use issues to permit reprinting and adaption from one extension program to another. Is it expecting too much to find materials developed in New England that are applicable in the Southwest? In general, the answer seems "No"; an excellent example is the North Carolina package that has been adapted by both Arkansas and South Dakota. A facilitating mechanism for sharing of materials between states might be the Functional Network in Land Use Issues sponsored by the Southern Rural Development Center. This Network is designed to bring together researchers and extension economists in an attempt to inventory the available literature, synthesize results, and present implications for action programs. It is still early but in the near future this approach can be more thoroughly evaluated. (*b*) Can extension do justice in awareness education without tracing the development and forces, social and economic, behind present land use patterns? We think not. What was done in *Texas Land Use* (Texas Agricultural Extension Service), in Raup's "Achieving Land Use in the Public Interest," and in the League of Women Voters' "Land Use: Can We Keep Public and Private Rights in Balance?" needs to be done for every state having an awareness education effort. Whether it is oil in Texas, irrigation in California, or coal in Kentucky, there have been important social and economic variables that have been prime

determinants of the dominant land use patterns of development. These ought to be brought into sharp relief against some of the new determinants: redistribution of property rights, expanding federal regulations impinging on land use, reversal in population centralization, and the amelioration of externality problems. (*c*) There is a clear need for additional effort in laying out the policy alternatives. In many cases, the public perceives the land use control issue as "zoning versus no regulation." This is an unfortunate situation but a challenging opportunity for the educator. As W. L. Gibson, Jr., has recently written:

> The problems involved in developing a workable land-use policy are not ones of zero-risks, zero-use conflicts, or zero-restraints on resource use. The problems are how to develop enough public support at the appropriate levels of government in which capability exists to choose among alternative courses of action consistent with present knowledge. Such public support can arise only from an enlightened public. (p. 2)

(*d*) Research now published or underway provides some information on the consequences and impacts of land use controls. This information, where available, needs to be digested, synthesized, popularized, and published for lay consumption. Where the information is not available, research should be initiated if only on an informal basis. This information is critical in regard to determining the extent to which commercial agriculture and rural areas will bear the burden of expanded land use controls: shifting property tax burdens, restrictions on acceptable uses, and increases in agricultural production costs.

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Microeconomic Output Supply and Factor Demand Functions in the Agriculture of the Province of Taiwan

Pan A. Yotopoulos, Lawrence J. Lau, and Wuu-Long Lin

Normalized restricted profit functions have been employed in the empirical analysis of agricultural production by Lau and Yotopoulos in a cross-sectional study of farms in India. The objective of the present study is to apply the same methodology to the analysis of data from a cross section of farm households in the Province of Taiwan, Republic of China. Two features distinguish this study from the earlier one. First, the number of variable inputs is increased from one to four. Second, the hypothesis of structural change as between successive cross sections is tested. Such a test of structural change may be interpreted as a test of the stability of the estimated production function parameters.

The Normalized Restricted Profit Function

The production function for each agricultural household is assumed to be Cobb-Douglas in form. Four variable inputs, labor, animal labor, mechanical labor, and fertilizer, and two fixed inputs, land and fixed assets, are distinguished. The normalized restricted profit function (for a discussion of the normalized restricted profit function as applied here and its properties, see McFadden, Diewert, Jorgenson and Lau [1974a, 1974b], Lau [1975], and Lau and Yotopoulos)[1] is given by

$$(1)\quad \ln \Pi^* = \ln A^* + \alpha^*_L \ln q_L + \alpha^*_A \ln q_A + \alpha^*_M \ln q_M + \alpha^*_F \ln q_F + \beta^*_K \ln Y_K + \beta^*_T \ln Y_T + \sum_{i=1}^{7} \delta_i D_i,$$

where Π^* is restricted profit (current revenue less current variable costs), per farm, normalized by the price of output; q_L is the money wage per day normalized by the price of output; q_A is the money animal wage per day normalized by the price of output; q_M is the money mechanical wage per hour normalized by the price of output; q_F is the money price of fertilizer per kilogram normalized by the price of output; Y_K is the quantity of fixed farm assets in New Taiwan dollars; Y_T is the farm area in hectares; and D_i's are dummy variables corresponding to agricultural regions.

The demand for each variable factor of production is obtained, using Shephard's Lemma (for a derivation of Shephard's Lemma, see, e.g., Lau [1969]), by differentiating the normalized profit function with respect to the normalized price of that factor: $X_i = -\frac{\partial \Pi^*}{\partial q_i}$, $i = L, A, M, F$, which implies that

$$(2)\quad \frac{-q_i X_i}{\Pi^*} = -\frac{\partial \ln \Pi^*}{\partial \ln q_i} = \alpha^*_i,\ i = L, A, M, F,$$

where X_L is total labor days, X_A is total animal work days, X_M is total hours of mechanical equipment, and X_F is total quantity of fertilizer in kilograms.

From the definition of normalized profit the output supply equation may be obtained:

$$(3)\quad V = \Pi^*(q, Y) - \sum_i \frac{\partial \Pi^*(q, Y)}{\partial q_i} q_i.$$

Given any five equations of types (1) through (3), the sixth may be obtained from the normalized profits identity, $\Pi^* = V + \sum_i q_i X_i$. Hence, one can drop one of the six equations. We concentrate therefore on equations (1) and (2).

Estimates of all the parameters can be obtained from equation (1). Alternatively, one can estimate the parameters of the variable factors of production from equations of type (2). Under the hypothesis of profit-maximizing and price-taking behavior on the part of the farms, the parameters in equation (2) are equal to the corresponding parameters in equation (1). (For a derivation of this result, see, e.g., Lau and Yotopoulos.) This, then, provides the basis for an explicit test of the hypothesis of profit maximization. If the hypothesis of profit maximization is not rejected, we proceed, conditionally, to test two subsidiary hypotheses: constant returns to scale in production and absence of structural change.

Constant returns to scale implies that $\beta^*_K + \beta^*_T = 1$. (For a derivation of this result, see, e.g., Lau and Yotopoulos.) Absence of structural change implies that the estimated parameters of the nor-

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[1] In the last reference, the term "UOP profit function" rather than "normalized profit function" is used.

malized profit function are identical as between 1967 and 1968. A generalization of the Chow test is employed to test the hypothesis of the absence of structural change.[2]

The Data

The bulk of the data for this research was derived from Provincial Government of Taiwan, Department of Agriculture and Forestry, *Report of Farm Record-Keeping Families in Taiwan, 1967* and *1968*, hereafter referred to as the *Report*. This source was supplemented with data from Provincial Government of Taiwan, Department of Agriculture and Forestry, *A Report on Cost Survey of Agricultural Products, 1967* and *1968* and *Taiwan Agriculture Yearbook, 1967* and *1968*. A brief description of the data follows; more specific information is given in Yotopoulos, Lau, and Lin.

The basic data source provides information on household averages of about 400 farm households grouped according to five sizes of operation (from below 0.5 hectare to 2.0 hectares and above by 0.5 hectare steps) and eight agricultural regions. The number of observations available, therefore, is about forty for each year. The information includes the expenditures on the variable factors of production and the quantities of labor, animal labor, and mechanical labor. The wage rate is also computed from the *Report*. The animal labor and mechanical labor wage rates are computed from subsidiary sources. The computation of fertilizer price is rather involved and is detailed in Yotopoulos, Lau, and Lin. An output price index is constructed for each observation that takes into account the differential composition of output using subsidiary data at the hsien (or county) level.

Fixed farm assets are given in New Taiwan dollars and include investment in plant and live capital in the *Report*. From these two components, the fixed input component of farm assets are estimated. Cultivated land, which is reported separately for paddy land and dry land in hectares, is homogenized into paddy land-equivalents.

Statistical Method

Given the assumptions of profit-maximizing and price-taking behavior on the part of the farm households, the strong concavity of the production function in the variable inputs, and the short-run constancy of the quantities of fixed assets and land, the farm's decision variables are the quantities of output and the four variable inputs. The prices of output and the four variable inputs as well as the quantities of the fixed inputs are predetermined and not subject to change by the action of any one farm in the short run. Consequently, output, labor, animal labor, mechanical labor, and fertilizer are jointly dependent variables, and the prices of output and variable inputs and the quantities of fixed inputs are the predetermined variables of the model. An alternative set of five jointly dependent variables consists of profits and expenditures on each of the four variable factors of production. Thus, in equations (1) and (2), the variables on the left-hand side may be regarded as the jointly dependent variables and those on the right-hand side may be regarded as the predetermined variables. It is further assumed that the matrix of independent variables is constant in repeated samples and has full rank with probability one.

As in the earlier study of Lau and Yotopoulos, we follow the usual and admittedly ad hoc practice of assuming an additive error identically distributed across farms with zero expectation and finite variance for each of the equations (1) and (2). For the same farm, the covariance of the errors of any two of the three equations is assumed to be nonzero. However, the covariance of the errors of any two equations corresponding to different farms is assumed to be identically zero.

Under these conditions, ordinary least squares applied to each of the equations (1) and (2) separately will be consistent but not necessarily efficient. Zellner's method, on the other hand, is asymptotically efficient, and it is the method used, with appropriate linear constraints imposed as necessary.

Empirical Results

To test the validity of the restrictions implied by the hypotheses of profit maximization, constant returns, and absence of structural change, test statistics based on F-ratios are used. The overall level of significance is set at 0.05. First, a level of significance of 0.01 is assigned to the test of the equality restriction implied by profit maximization in 1967 and in 1968, respectively. Then, a level of significance of 0.03 is assigned to the tests on the structure of the technology, that is, the test of constant returns to scale in 1967 and in 1968 and the test of structural change, all conditional on the validity of the hypothesis of profit maximization. Because these two sets of tests are "nested," under the null hypothesis the sum of levels of significance of the two sets of tests provides a close approximation to the level of significance for both sets of tests simultaneously. (For a discussion of "nested" hypotheses, see Scheffé; for a discussion of simultaneous statistical inference, see Miller.) A level of significance of 0.01 is assigned to each of the three hypotheses of constant returns in 1967, constant returns in 1968, and structural change.

The first hypothesis to be tested is that of profit maximization: H_0: $\alpha_i^{*\Pi} = \alpha_i^{*i}$, $i = L, A, M, F,$

[2] The Chow test is not directly applicable because there are five stochastic equations in each period and the errors are not assumed to be homoscedastic.

Table 1. *F*-Ratios for Tests of Profit Maximization and Constant Returns to Scale, 1967 and 1968

Degrees of Freedom		Equality*	Constant Returns to Scale Conditional on Equality*	Critical Values of *F*-Ratios Levels of Significance 0.01	0.05
Year 1967	(4,177)	2.075		3.42	2.42
	(1,181)		0.302	6.77	3.90
Year 1968	(4,182)	1.790		3.42	2.42
	(1,186)		0.712	6.77	3.90

* Restrictions are defined in text.

separately for 1967 and 1968, where the superscript denotes the equation from which the parameter is estimated. Conditional on the validity of the equality hypothesis, the hypothesis of constant returns to scale is tested separately for 1967 and 1968: H_0: $\beta^*_K + \beta^*_T = 1$.

The test statistics are presented in table 1. At a 0.01 significance level each, the hypothesis that the restrictions implied by profit maximization are valid for 1967 and 1968 cannot be rejected. Proceeding conditionally on the validity of the hypothesis of profit maximization, the hypothesis of constant returns to scale cannot be rejected. Critical values for our test statistics for levels of significance equal to 0.01 and 0.05 are presented so that the reader can evaluate the test results for alternative allocations of the overall levels of significance among stages of the test procedure.

The parameter estimates for 1967 and 1968 are presented separately in tables 2 and 3. In the first column are the coefficients estimated from ordinary least squares. In the second column, the co-

Table 2. Joint Estimation of the Normalized Profit Function and Factor Share Equations for Variable Inputs, 1967

		Estimated Coefficients			
			Zellner's Method with Restrictions [c]		
Year 1967 Profit Function	Parameter	Single Equation OLS	Unrestricted	Equality Restrictions	Equality and Constant Returns Restrictions
Constant [a]	$\ln A^*$	9.793	9.487	10.350	9.979
		(4.858)[b]	(4.153)	(1.973)	(1.538)
Labor	$\alpha_L{}^{*\Pi}$	−2.116	−1.268	−0.825	−0.818
		(0.481)	(0.411)	(0.132)	(0.131)
Animal labor	$\alpha_A{}^{*\Pi}$	0.450	0.378	−0.041	−0.041
		(0.201)	(0.172)	(0.008)	(0.008)
Mechanical labor	$\alpha_M{}^{*\Pi}$	0.429	0.003	−0.019	−0.019
		(1.350)	(1.154)	(0.005)	(0.005)
Fertilizer	$\alpha_F{}^{*\Pi}$	−1.190	−0.841	−0.225	−0.224
		(0.379)	(0.324)	(0.020)	(0.019)
Fixed assets	$\beta_K{}^*$	0.153	0.130	0.076	0.110
		(0.232)	(0.198)	(0.182)	(0.137)
Land	$\beta_T{}^*$	1.060	0.970	0.913	0.890
		(0.216)	(0.184)	(0.148)	(0.137)
Factor Equations					
Labor	$\alpha_L{}^{*L}$	−0.883	−0.883	−0.825	−0.818
		(0.143)	(0.143)	(0.132)	(0.131)
Animal labor	$\alpha_A{}^{*A}$	−0.044	−0.044	−0.041	−0.041
		(0.008)	(0.008)	(0.007)	(0.008)
Mechanical labor	$\alpha_M{}^{*M}$	−0.020	−0.020	−0.019	−0.019
		(0.005)	(0.005)	(0.005)	(0.005)
Fertilizer	$\alpha_F{}^{*F}$	−0.238	−0.232	−0.225	−0.224
		(0.021)	(0.021)	(0.010)	(0.019)

[a] Coefficients corresponding to the dummy variables are omitted for lack of space.
[b] Numbers in parentheses are estimates of asymptotic standard errors.
[c] The restrictions are defined in text.

Table 3. Joint Estimation of the Normalized Profit Function and Factor Share Equations for Variable Inputs, 1968

Year 1968 Profit Function	Parameter	Single Equation OLS	Estimated Coefficients: Zellner's Method with Restrictions[c] Unrestricted	Equality Restrictions	Equality and Constant Returns Restrictions
Constant[a]	$\ln A^*$	9.085	6.007	11.870	11.540
		(4.080)[b]	(3.271)	(1.415)	(1.277)
Labor	$\alpha_L^{*\Pi}$	−1.370	−0.785	−0.975	−0.981
		(0.501)	(0.402)	(0.127)	(0.127)
Animal labor	$\alpha_A^{*\Pi}$	−0.272	−0.124	−0.055	−0.055
		(0.194)	(0.156)	(0.006)	(0.006)
Mechanical labor	$\alpha_M^{*\Pi}$	0.763	1.259	−0.024	−0.024
		(1.270)	(1.018)	(0.005)	(0.005)
Fertilizer	$\alpha_F^{*\Pi}$	0.183	−0.140	−0.237	−0.238
		(0.462)	(0.371)	(0.019)	(0.019)
Fixed assets	β_K^*	0.151	0.093	−0.009	0.024
		(0.178)	(0.143)	(0.131)	(0.117)
Land	β_T^*	0.737	0.781	0.971	0.976
		(0.176)	(0.141)	(0.117)	(0.117)
Factor Equations					
Labor	α_L^{*L}	−1.086	−1.086	−0.975	−0.981
		(0.138)	(0.138)	(0.127)	(0.127)
Animal labor	α_A^{*A}	−0.057	−0.057	−0.055	−0.055
		(0.006)	(0.006)	(0.006)	(0.006)
Mechanical labor	α_M^{*M}	−0.024	−0.024	−0.024	−0.024
		(0.005)	(0.005)	(0.005)	(0.005)
Fertilizer	α_F^{*F}	−0.251	−0.251	−0.237	−0.238
		(0.020)	(0.020)	(0.019)	(0.019)

See table 2 for footnotes.

efficients estimated from Zellner's method without restrictions are given. These estimators are more efficient than the single-equation ordinary least squares estimators. Their efficiency, however, may be further improved, if one is willing to maintain the hypothesis of profit maximization and impose the corresponding restrictions. Such restricted estimates are reported in the third column. Finally, the fourth column provides coefficients estimated by Zellner's method imposing the linear constraints implied both by profit maximization and constant returns to scale.

Next, we test whether parameters of the normalized restricted profit function are the same in 1967 and in 1968. This test is of interest not so much because of the possibility of technical progress, inasmuch as the two years are consecutive, but because the test may indicate the degree of stability of the parameter estimates.

To test the validity of the hypothesis of absence of structural change, test statistics are derived in a manner similar to that of the Chow test. The principal difference between these test statistics and the Chow test lies in the fact that the former generalize the Chow test to the case in which there is more than one stochastic equation and the variance-covariance matrix of the system as a whole is not homoscedastic.

Specifically, the system of equations consisting of the natural logarithm of normalized profits and the four factor-share equations may be considered as one single univariate equation with a heteroscedastic variance-covariance matrix of errors. The test of structural change is equivalent to a test of whether the coefficients estimated from such a system for 1967 is the same as those estimated for 1968. In order to put the problem into canonical form so that it is suitable for the direct application of the Chow test, both the dependent and the independent variables of the system of five equations are transformed by premultiplying by a suitable matrix P that transforms the error of the system of equations into a homoscedastic disturbance. This matrix P has the property that $P \Sigma P' = I$, $P'P = \Sigma^{-1}$, where Σ is the variance-covariance matrix of the error of a typical observation of the five-equation system. Given a consistent estimator of Σ, a consistent estimator of P, say $\hat{P}$, can be computed. Using this $\hat{P}$, one may transform the 1967 and 1968 problems into an equivalent univariate problem with a homoscedastic variance-covariance matrix. The Chow test procedure is then carried out for 1967 and 1968 with the transformed problem in a straightforward manner.

Structural change between 1967 and 1968 is tested conditional on the validity of the hypothesis

Table 4. Joint Estimation of the Normalized Profit Function and Factor Share Equations for Variable Inputs, 1967 and 1968 Pooled

		Zellner's Method			
Function	Variables and Parameters	Six Restrictions	Thirteen Restrictions	Fourteen Restrictions	Fifteen Restrictions
Profit function[a]	const. ($\ln A^*$)			11.11	10.69
				(1.8348)	(1.6276)
	const. ($\ln A^*$)[1]	11.25	10.84		
		(2.005)[b]	(1.916)		
	const. ($\ln A^*$)[2]	11.40	10.89		
		(1.943)	(1.887)		
	$\ln q_L$ (α^*_L)	−0.9848	−0.9822	−0.9800	−0.9798
		(0.0482)	(0.0485)	(0.0483)	(0.0483)
	$\ln q_A$ (α^*_A)	−0.0479	−0.0375	−0.0351	−0.0356
		(0.0412)	(0.0412)	(0.0410)	(0.0410)
	$\ln q_M$ (α^*_M)	−0.0197	0.0001	−0.0012	−0.0017
		(0.0469)	(0.0714)	(0.0462)	(0.0463)
	$\ln q_F$ (α^*_F)	−0.2395	−0.2297	−0.2300	−0.2306
		(0.0444)	(0.0445)	(0.0445)	(0.0445)
	$\ln Y_K$ (β^*_K)	0.0188	0.0535	0.0291	0.0702
		(0.1873)	(0.1808)	(0.1735)	(0.1530)
	$\ln Y_T$ (β^*_T)	0.9474	0.9100	0.9274	0.9298
		(0.1612)	(0.1571)	(0.1530)	
Labor share function	$-\frac{q_L X_L}{\Pi} = \alpha^*_L$	−0.9848	−0.9822	−0.9800	−0.9798
		(0.04816)	(0.0485)	(0.0483)	(0.0483)
Animal labor share function	$-\frac{q_A X_A}{\Pi} = \alpha^*_A$	−0.0479	−0.0375	−0.0351	−0.0356
		(0.0412)	(0.0412)	(0.0410)	(0.0410)
Mechanical labor share function	$-\frac{q_M X_M}{\Pi} = \alpha^*_M$	−0.0197	0.0001	−0.0012	−0.0017
		(0.0469)	(0.0714)	(0.0462)	(0.0463)
Fertilizer share function	$-\frac{q_F X_F}{\Pi} = \alpha^*_F$	−0.2395	−0.2297	−0.2300	−0.2306
		(0.0444)	(0.0445)	(0.0445)	(0.0445)
	R^2	0.9858	0.9855	0.9855	0.9855
	$\beta^*_K + \beta^*_T$	0.9662	0.9635	0.9565	1.0000

[a] Superscripts 1 and 2 of the constant refer to 1967 and 1968, respectively. Coefficients corresponding to the dummy variables are omitted for lack of space.
[b] Numbers in parentheses are estimates of asymptotic standard errors.

of profit maximization in 1967 and 1968. The test of structural change may be decomposed into three sequential stages: (*a*) no structural change in the parameters of the normalized profit function between 1967 and 1968, except for the intercept term and the dummy variables; (*b*) no structural change except for the intercept; and (*c*) no structural change. Under (*c*), the two normalized profit functions for 1967 and 1968 are identical in every respect. A level of significance of 0.0033 is allocated to each of the three stages of the test of structural change. These three tests are "nested"; thus, under the null hypothesis the sum of levels of significance of the three tests provides a close approximation to the level of significance for the three tests simultaneously. The test statistics corresponding to each of the three stages are, respectively: $F(6{,}369) = 1.693$, $F(7{,}375) = 2.004$, and $F(1{,}382) = 0.3764$. At the 0.0033 significance level, none of the three stages of hypotheses can be rejected. Thus, technology is apparently stable between 1967 and 1968.

On the basis of the test of structural change, the two cross sections of data are combined and parameters reestimated for the normalized profit function. These parameter estimates are reported in table 4. The first column reports the coefficients estimated without the equality restrictions on either the intercept or the dummy variables. The second column reports the coefficients estimated without the equality restriction on the intercept. The third column reports the coefficients estimated with all the equality restrictions imposed. The coefficients with all the equality restrictions and constant returns imposed are given in the fourth column. For the purpose of further discussion and analysis,

Table 5. Comparison of Alternative Estimates of the Production Elasticities

	Indirect Estimates This Study	Direct Estimates				Factor Share Estimates
		This Study	Wang	Wang	Chen	Ho
	Cross Section 1967–68	Cross Section 1967–68	Cross Section Sugarcane 1957	Cross Section Other Crops 1957	Cross Section 1963	Time Series 1903–60
Labor	0.4359	0.2610	0.25	0.33	0.065	0.4524
Animal labor	0.0158	0.0340				
Mechanical	0.0008	0.0237	0.34	0.31	0.513	0.1929
Fertilizer	0.1026	0.5446				
Fixed assets	0.0312	0.0142			0.158	0.1085
Land	0.4137	0.0614	0.36	0.44	0.230	0.2462
Sum of elasticities	1.0000	0.9389	0.95	1.08	0.966	1.0000

Sources: Wang, reported in Heady and Dillon, p. 628; Chen, reported in Chen, p. 19; Ho, reported in Ho, p. 63.

these final estimates are adopted, in view of our results of hypothesis testing. The coefficient estimates of the normalized profit function for 1967 and 1968 pooled satisfy the conditions of monotonicity and convexity.

Comparison with Other Studies

Using the parameter estimates of the normalized restricted-profit function reported in table 4, one may derive the indirect estimates of the production elasticities of the Cobb-Douglas production function that underlies the normalized restricted-profit function. These estimates are consistent estimates of the production-function elasticities. They are referred to as indirect estimates so as to distinguish them from the direct estimates, which are obtained by estimating the production function directly.

Both the indirect and the direct production-function elasticities for the pooled data are reported in table 5, as well as production-function elasticities obtained by other studies of Taiwan agriculture. Our indirect estimates of the production elasticities are not strictly comparable to the directly estimated production elasticities. The former estimates are consistent and asymptotically efficient given the stochastic assumptions. The latter estimates are generally inconsistent because of the existence of simultaneous equation bias. In addition, the estimates obtained from other studies may also be different because of differences in the type of data (cross section or times series), the time period, the type of output, and the degree of disaggregation of the inputs.

The differences among the alternative direct estimates are striking, as are the differences between our indirect estimates and direct estimates of the same parameters. The land elasticity obtained from our direct estimation of the production function appears to be too low. The labor elasticity also appears to be low in view of the significant labor share (40%) in total cost. We attribute these biases in the directly estimated elasticities to the existence of simultaneous equations bias in the direct estimation of the production function. However, in a model with five stochastic equations, it is difficult to isolate a priori the precise cause of the direction and magnitude of these biases.

Our indirect estimates are consistent with the a priori expectations of economic theory. They indicate that labor and land are by far the two most important factor inputs. Fertilizer is next in importance with an elasticity of approximately 0.10. Animal and mechanical labor inputs do not figure prominently in 1967 and 1968. Fixed assets also has a low elasticity. These findings are consistent with the observation that while Taiwan agriculture has undergone substantial technological progress in the past quarter of a century, most of the innovations have been of the labor-using type. Thus, labor remains the most important variable input of production.

Conclusions

Using the estimates from the fourth column of table 4, one can compute the output supply and factor demand own- and cross-price elasticities as well as elasticities with respect to the fixed factors of production. These elasticities are presented in table 6. The own-price elasticities of output and variable inputs are all greater than one in absolute value, indicating an elastic response of factor utilization. The cross-price elasticities, on the other hand, are rather low, with the exception of the price of output and the price of labor. The cross-price elasticities

Table 6. Own- and Cross-Price Elasticities and Elasticities with Respect to the Fixed Inputs, 1967 and 1968 Pooled

	P_A	q_L	q_A	q_M	q_F	Y_K	Y_T
V_S	1.2477	−0.9798	−0.0356	−0.0017	−0.2306	0.0702	0.9298
X_L	2.2477	−1.9798	−0.0356	−0.0017	−0.2306	0.0702	0.9298
X_A	2.2477	−0.9798	−1.0356	−0.0017	−0.2306	0.0702	0.9298
X_M	2.2477	−0.9798	−0.0356	−1.0017	−0.2306	0.0702	0.9298
X_F	2.2477	−0.9798	−0.0356	−0.0017	−1.2306	0.0702	0.9298

between the variable inputs are all negative, indicating that all the variable inputs are more complements than substitutes. The output supply and factor demands appear to be quite sensitive to changes in output price.

The elasticities of output supply and factor demands with respect to the fixed factors of production show that there is almost unitary elasticity with respect to land. On the other hand, the elasticities with respect to fixed assets appear to be negligible. These elasticities with respect to the fixed inputs measure the response of price-taking profit-maximizing farms with respect to an exogenous change in the fixed factors, holding the prices of output and variable inputs constant. Thus, they reflect the *mutatis mutandis* effect of a change in the quantity of a fixed input, allowing the farm to adjust its output and variable inputs optimally and are not comparable with the production function elasticities, which reflect the *ceteris paribus* effect of a change in the quantity of a fixed input, holding the quantities of the variable inputs constant. The *mutatis mutandis* effect is much greater than the *ceteris paribus* effect, as expected. For purposes of prediction and policy analysis, frequently it is the *mutatis mutandis* elasticity that is relevant.

This paper extends an earlier study done by Lau and Yotopoulos. It is found that the hypothesis of profit maximization cannot be rejected. Thus, the agricultural households in Taiwan may therefore be regarded as efficient producers at least within their own environment.[3] Moreover, it appears that even in situations in which the direct production-function estimation yields unreasonable estimates, as is in the present case, the normalized profit function and factor demand functions approach gives reasonable estimates for the parameters of the production function.[4] Hence, perhaps this approach should be given more weight in the empirical analysis of production using data from nonexperimental situations.

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[3] In retrospect, as a referee pointed out, a substantially higher level of significance for the entire sequence of tests could have been used without rejecting any of the null hypotheses. This higher level of significance, being associated with greater power for rejection, lends additional support for the validity of the final model used.

[4] In a parallel study of Thailand agriculture, Adulavidhaya, Kuroda, Lau, and Yotopoulos also find that the normalized restricted profit function approach gives reasonable estimates of the production function elasticities, whereas the direct estimation of the production function gives unreasonable estimates.

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The Demand for Agricultural Commodities in Ghana: An Application of Nonlinear Two-Stage Least Squares with Prior Information

Walter Haessel

Very little is known about the price responsiveness of either Ghanaian consumers or agricultural producers (see Agbetsiafa, Bateman, and Haessel and Appiah). This paper reports on some attempts to estimate price and income elasticities of demand for some of the major staples consumed in Ghana. Prior information on the income elasticities was incorporated using the mixed estimation procedure outlined by Theil and Goldberger. The method of incorporating the prior information resulted in a nonlinear estimation problem.

The underlying economic model and related statistical methodology are outlined in the following section. This is followed by a brief discussion of the data and a presentation of the results. The paper concludes with an investigation of the relative importance of price and income elasticities in projecting demand for foodstuffs.

Method of Analysis

The quantity of any commodity consumed in any period is assumed equal to total domestic production plus net imports. The quantity of a particular commodity produced in any one season depends on the acreage planted in the previous planting season, the yield of the commodity, and the intensity with which it is harvested. The acreage planted does not depend on the price at harvest time but rather on the price expected at harvest. To the extent that yield depends on husbandry, and husbandry and harvesting intensities in turn depend on current price, current production will depend on current price. However, it is assumed that these latter two influences are relatively unimportant and production of each commodity is assumed to be predetermined.

With the exception of rice, Ghanaian net imports of the commodities considered in this study are negligible and amount to less than 1% of domestic production. For rice, however, imports were relatively large throughout the sample period and in some years exceeded domestic production. Consequently, the domestic price of rice is determined by the import price and the quantity imported is determined by excess demand. For the remaining commodities, however, prices must adjust to clear the market since availability per capita is essentially predetermined by planting decisions in the previous year.

The quantity of a particular commodity demanded by an individual consumer depends on the commodity's own price, the prices of substitutes and complements, and the consumer's income. Assuming a log-linear form for the demand equations,

$$(1) \quad q_{ti} = a_{i0} + \sum_{j=1}^{n} a_{ij}p_{tj} + e_i y_t + u_{ti},$$
$$i = 1, \ldots, n, \text{and } t = 1, \ldots, T,$$

where q_{ti} is the natural logarithm of the quantity of commodity i consumed per capita,[1] p_{tj} is the logarithm of the price per unit of commodity j, y_t is the logarithm of per capita income, u_{ti} is a statistical error term, and the a_{ij}'s and e_i's are parameters (elasticities) to be estimated. The t subscripts refer to the time period. Specifically, $q_{ti} = \ln[(S_{ti} + M_{ti})/N_t]$, where S_{ti} and M_{ti} are domestic production and net imports of commodity i, respectively, and N_t is population. Based on the above discussion, q_{ti} is predetermined for every commodity except rice, which is endogenous. However, the price of rice is exogenous and all $n - 1$ remaining prices are endogenous. Per capita income is exogenous.

Let commodity n be rice. For each of the i equations other than rice there are $n - 1$ included

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[1] Demand equations should always be estimated on a per capita basis from time-series data. Consider an economy where prices and incomes per capita remain unchanged but total population is changing. In the absence of changes in income distribution and changes in tastes and preferences, there is no reason to expect per capita consumption to change. Thus, we have the relationship between aggregate and per capita consumption of $Q = Nq$ and $dQ = qdN + Ndq$, where N is population and Q and q denote aggregate and per capita consumption. In the above case, $dq = 0$ and $dQ = qdN$. Suppose that the demand equation is specified in aggregate form as $Q = f(P, Y)$, where P is the price of the commodity, $Y = Ny$ is aggregate income, and y is income per capita. Then $dQ = f_P dP + f_Y(Ndy + ydN)$, where the subscripts denote partial derivatives. Under the above assumptions of $dP = dy = 0$, we expect $yf_y = q$. The way to ensure this is to estimate the demand equation on a per capita basis.

[2] Meinken, Rojko, and King reached a similar conclusion for a slightly simpler case in which all the quantities were considered predetermined.

endogenous variables (the prices) and $n - 2$ excluded exogenous variables (all excluded quantities except rice). The rice equation includes n endogenous variables (the quantity of rice and $n - 1$ prices), and $n - 1$ predetermined quantities are excluded. Thus, each of the equations is just identified since the number of excluded predetermined variables is just equal to one less than the number of included endogenous variables.[2] Hence, identical estimates could be obtained by indirect least squares (ILS) and 2SLS. Both methods were applied, but only the 2SLS results are reported since the approach turns out to be simpler.[3] This is especially true in view of the prior estimate of the income elasticity (e_i) that was available from a cross-sectional study. This prior estimate was combined with the time-series sample data using the Theil-Goldberger mixed estimation technique.[4]

Equation (1) is rewritten for all T observations on commodity i in matrix form as

$$(2) \qquad Q_i = PA_i + Ye_i + U_i,$$

where $Q_i = [q_{1i}, q_{2i}, \ldots, q_{Ti}]'$, $Y = [y_1, y_2, \ldots, y_T]'$, and $U_i = [u_{1i}, u_{2i}, \ldots, u_{Ti}]'$ are $T \times 1$ vectors of variables and error terms; $P = [\iota, P_1, P_2, \ldots, P_n]$ is a $T \times (n + 1)$ matrix consisting of a $T \times 1$ column of 1's (ι) and n column vectors of prices $P_j = [p_{1j}, p_{2j}, \ldots, p_{Tj}]'$ of dimension $T \times 1$; $A_i = [a_{i0}, a_{i1}, \ldots, a_{in}]'$ is an $(n + 1) \times 1$ vector of price elasticity coefficients to be estimated; and e_i is an income elasticity coefficient to be estimated.

Let e^*_i denote the prior point estimate of e_i. The variance of e^*_i was unknown, but since it is believed that e_i should not be negative, a variance was chosen so that $\sigma_{e^*_i} = e^*_i/k$. Three alternative values for k were used: 1.29, 1.645, and 2. These correspond to values such that for a normal distribution, an interval of $\pm k\sigma$ about the mean contains approximately 80%, 90%, and 95% of the observations, respectively.

The prior information for the rice equation can be incorporated by estimating an equation of the form

$$(3) \qquad \begin{bmatrix} Q_n \\ e^*_n \end{bmatrix} = \begin{bmatrix} P \\ 0 \end{bmatrix} A_n + \begin{bmatrix} Y \\ 1 \end{bmatrix} e_n + \begin{bmatrix} u_n \\ v_n \end{bmatrix},$$

where 0 is a $1 \times (n + 1)$ row vector of 0's and v_n is an error term such that $e^*_n - e_n = v_n$, $Ev_n = 0$, and $Ev_n^2 = \sigma_{e^*_n}^2$. Equation (3) was estimated by generalized 2SLS under the assumption that u_n and v_n are independent but have different variances.[5]

Obtaining estimates of equations other than rice is slightly more complicated since the left-hand-side variables are exogenous. These equations are rewritten in price-dependent form as

$$(4) \qquad P_i = X_i\alpha_i + Y\delta_i + \epsilon_i,$$

where

$$X_i = \begin{bmatrix} 1 & p_{11} & \cdots & p_{1,i-1} & q_{1i} & p_{1,i+1} & \cdots & p_{1n} \\ 1 & p_{21} & \cdots & p_{2,i-1} & q_{2i} & p_{2,i+1} & \cdots & p_{2n} \\ \vdots & \vdots & & \vdots & \vdots & \vdots & & \vdots \\ 1 & p_{T1} & \cdots & p_{T,i-1} & q_{Ti} & p_{T,i+1} & \cdots & p_{Tn} \end{bmatrix}$$

is a $T \times (n + 1)$ matrix, $\alpha_i = (-1/a_{ii})[a_{i0}, a_{i1}, \ldots, a_{i,i-1}, -1, a_{i,i+1}, \ldots, a_{i,n}]'$ is an $(n + 1) \times 1$ column vector of parameters, $\epsilon_i = -(1/a_{ii})u_i$ is a $T \times 1$ vector of disturbances, $\delta_i = -e_i/a_{ii}$ is a scalar, and P_i and Y are as defined above. The parameters in α_i and δ_i are nonlinear combinations of the parameters of equation (1). The prior estimate of e_i was incorporated by estimating an equation of the form

$$(5) \qquad \begin{bmatrix} P_i \\ e^*_i \end{bmatrix} = \begin{bmatrix} X_i \\ 0_1 \end{bmatrix} \alpha_i + \begin{bmatrix} Y \\ 0_2 \end{bmatrix} \delta_i + \begin{bmatrix} 0_3 \\ 1 \end{bmatrix} e_i + \begin{bmatrix} \epsilon_i \\ v_i \end{bmatrix},$$

where 0_1, 0_2, and 0_3 are zero vectors of dimension $1 \times (n + 1)$, 1×1, and $T \times 1$, respectively. This equation must be estimated in terms of the original parameters (a_{ij}'s and e_i) rather than in terms of the α_i and δ_i. This was done by using Amemiya's nonlinear 2SLS procedure.[6] Since the model is linear in the endogenous variables but nonlinear in the parameters, the NL-2SLS estimates will have the same asymptotic efficiency properties as 2SLS in the linear case.

By utilizing the residuals from estimates of equations (3) and (5), it is possible to obtain estimates of the contemporaneous covariances among the equations in a manner identical to that used in obtaining the contemporaneous covariance matrix in 3SLS. This estimate of the covariance matrix can then be used to estimate all n equations as a simultaneous system and the resulting estimates will be nonlinear 3SLS. (The iterative procedure used was similar to that outlined by Gallant.)

Data

Consistent sets of data on net imports, prices, and production from 1953 to 1970 are available for rice, maize, sorghum, millet, cassava, yams, and cocoyams. To reduce the number of variables, sor-

[3] In the Meinken case, ILS is easier to apply than in the present case, since the relationship between the reduced form and the structural equations is much simpler.

[4] The advantage of using a mixed estimation procedure over assuming an exact constraint is that the former method utilizes information from both the sample and the prior estimate, whereas the latter uses only the prior information and completely ignores the information in the sample. The latter procedure is appropriate only if it is known with certainty that the prior estimate is correct. In other words, the variance of the prior is 0, which is a special case of mixed estimation.

[5] This was done by multiplying the last row of equation (3) by $\hat{\sigma}_n/\sigma_{e^*_n}$, where $\hat{\sigma}_n$ is an estimate of the standard deviation of u_n obtained from residuals of 2SLS estimates of equation (2).

[6] The heteroscedasticity problem was solved in the same way as for equation (3).

ghum was aggregated with millet (henceforth referred to as millet) and yams and cocoyams were combined (henceforth yams) since these commodities are fairly close substitutes. This left a total of five commodities. For purposes of estimation, it was found advantageous to combine yams with cassava (roots) and millet with maize (cereals).

One data problem relates to the accuracy of the quantity data. Data on production are very difficult to collect, and the methods used suggest that the production figures are probably measured with error. Furthermore, if inventories carried over from one period to the next vary substantially over time, an error in variables problem is introduced. However, given the lack of storage facilities in Ghana and the problem of storing commodities for extended periods of time in tropical climates, the carry-over stocks will be negligible and this should not be a serious problem.

The only price data available for foodstuffs in Ghana for any reasonably long period of time are wholesale prices. In estimating demand equations, retail rather than wholesale prices should be used. The consequence of using wholesale prices was investigated using wholesale and retail price indexes for locally produced foodstuffs. The evidence indicated that the elasticity of retail prices with respect to wholesale prices is 1. If this is true for individual commodities, then the retail and wholesale price elasticities of demand would be identical.

Perhaps the most crucial datum of the entire study is the expenditure elasticity for starches estimated by Ord on the basis of a cross-sectional household expenditure survey. This value of 0.78 (estimated for starches as a group and published without its standard error being given) was used as the prior estimate of the income elasticity (e^*_i) of each of the commodities. This estimate is consistent with expenditure elasticities reported by Kaneda and Johnson for three urban areas in Ghana.

Results

Three assumptions were utilized regarding the certainty of the prior information. Since the resulting estimates were all quite similar, only the estimates that gave the least weight to the prior information are reported (i.e., $k = 1.29$).

The NL-3SLS procedure failed to converge for the five commodity equations. The resulting NL-2SLS estimates are reported in part A of table 1. The estimates of the income elasticity are all positive and remarkably close to the prior estimate of 0.78 in all cases except yams. The sign of the own-price elasticity is negative in every case with the exception of that for millet. The own-price elasticity of maize seems larger in absolute value than might be expected on a priori grounds. Thus, maize and millet were aggregated into a single commodity (cereals) and the system was reestimated.

The resulting four-commodity equations are reported in part B of table 1 and conform to a priori expectations with respect to negative own-price elasticities and positive income elasticities. The NL-3SLS procedure was applied to the four-commodity case but, once again, it failed to converge. Thus, the size of the problem was reduced further by aggregating cassava and yams to form a new commodity called roots. In this case, the NL-3SLS procedure converged and the resulting estimates are reported in part C of table 1. The results conform with a priori expectations regarding signs of direct price and income elasticities. The estimates of the income elasticities differ more from 0.78 for the three-commodity estimates than for the four- and five-commodity estimates. This may be due to the fact that since fewer parameters are being estimated relative to the number of observations, the sample information has relatively more weight.

In summary, the foregoing estimates suggest that consumers in Ghana are indeed very price responsive. The direct-price elasticities, which tended on the whole to be better estimated than the cross-price elasticities (in the sense of being larger in relation to their standard errors), all exceed 1 in absolute value with the exception of cassava in the four-commodity regressions.

Agricultural Commodity Projections

The usual method of projecting demand for agricultural commodities consists of using income (or expenditure) elasticities and extrapolating on the basis of some rate of growth of income per capita and population. Prices are usually assumed to remain constant and their effects on consumption are ignored (see Ord, for example). The relatively large price elasticities found in this study suggest this could result in substantial errors if there are any changes in the relative prices of the various food commodities. Ignoring the error term, taking the total differential of equation (1), and rearranging yields

$$(6) \qquad D^*_i = \sum_{j=1}^{n} a_{ij} p^*_j + e_i y^* + N^*,$$

where D^*_i, p^*_j, y^*, and N^* indicate percentage changes in aggregate consumption, prices, per capita income, and population, respectively. If all prices change by the same percentage p^*, then equation (6) simplifies to

$$(7) \qquad D^*_i = p^* \sum_{j=1}^{n} a_{ij} + e_i y^* + N^*.$$

Projected annual percentage rates of growth of demand are presented in table 2 on the basis of the NL-3SLS three-commodity estimates for assumptions for y^* of 0.5% and 1.0% per annum and rates

Table 1. Estimated Demand Equations

A. Five-Commodity Equations	Variable						
	Intercept	Price Maize	Price Millet	Price Cassava	Price Yams	Price Rice	Income
Maize	25.206	−12.914	6.113	2.580	−5.000	0.267	0.769
	(65.80)*	(48.79)	(29.11)	(9.94)	(15.82)	(4.28)	(0.46)
Millet	−4.689	−0.162	1.027	−0.255	2.058	0.150	0.780
	(3.98)	(0.71)	(0.70)	(0.34)	(0.71)	(0.41)	(0.46)
Cassava	6.496	−1.199	0.259	−1.248	−0.658	0.580	0.809
	(6.04)	(1.43)	(1.37)	(0.77)	(1.45)	(0.73)	(0.42)
Yams	9.787	1.586	−0.446	0.0306	−1.953	−0.802	0.651
	(6.45)	(1.28)	(1.27)	(0.61)	(1.76)	(0.66)	(0.24)
Rice	6.427	0.0206	−0.0745	−0.149	−0.377	−1.355	0.780
	(2.54)	(0.66)	(0.65)	(0.31)	(0.67)	(0.33)	(0.066)

B. Four-Commodity Equations	Variable					
	Intercept	Price Cereal	Price Cassava	Price Yams	Price Rice	Income
Cereals	10.975	−2.323	0.425	−2.223	0.443	0.712
	(6.82)	(1.58)	(0.64)	(1.93)	(0.75)	(0.52)
Cassava	10.385	−2.087	−0.841	−2.134	0.846	0.821
	(7.85)	(1.60)	(0.74)	(2.06)	(0.83)	(0.67)
Yams	18.159	−0.613	0.674		−0.391	0.658
	(10.24)	(2.28)	(0.89)	(3.33)	(1.02)	(0.50)
Rice	8.797	−0.577	0.00661	−1.029	−1.250	0.710
	(4.77)	(0.81)	(0.38)	(1.06)	(0.45)	(0.49)

C. Three-Commodity Equations	Variable				
	Intercept	Price Cereals	Price Roots	Price Rice	Income
Cereals	4.443	−1.689	−0.823	0.427	0.917
	(3.51)	(0.99)	(0.92)	(0.59)	(0.54)
Roots	6.969	−0.117	−1.748	−0.252	0.908
	(3.20)	(0.72)	(0.67)	(0.47)	(0.52)
Rice	5.912	−0.362	−0.746	−1.256	0.874
	(2.91)	(0.62)	(0.58)	(0.41)	(0.49)

* Standard errors of the coefficients are given in parentheses.

of change of prices of −1%, 0, and 1% per annum. The population growth rate is assumed to be 2.4% per annum.[7] The figures suggest that projecting commodity demands on the basis of changes in per capita income and population alone can result in serious errors if, in fact, the prices of the commodities in question change relative to the general price level.

Conclusions

The price elasticities estimated are fairly large in absolute value. This may, in part, be due to the poor quality of the data resulting in biased estimates. Using wholesale prices rather than retail prices may also introduce biases, although tests of this proposition indicated this was not the case.

The tentative conclusion based on the above evidence is that Ghanaian consumers respond significantly and substantially to changes in the prices of local foodstuffs. This is consistent with the limited information available on the price responsiveness in demand in other developing countries (see Alamgir and Berlage; Bussink; de Janvry, Bieri, and Nuñez; and Haessel). This demonstrates the importance of considering possible price changes in the planning process and emphasizes the importance of price policy in the agricultural sector. This is especially true when the growing evidence on demand responsiveness is combined with the well-documented supply responsiveness of agricultural

[7] This was the rate of growth of population in Ghana between the 1960 and 1970 census.

Table 2. Annual Percentage Rates of Growth of Demand for Three-Commodity Projections

y^*	0.5			1.0		
P^*	1	0	−1	1	0	−1
Cereals	1.01	2.86	4.70	1.47	3.32	5.16
Roots	0.74	2.85	4.97	1.19	3.31	5.43
Rice	0.47	2.84	5.20	0.91	3.27	5.64

producers in developing areas (see the extensive literature summarized by Krishna).

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Impact of New Agricultural Technology on Farm Income Distribution in West Godavari District, India

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In selected regions, Indian agriculture has experienced a substantial impact of science and "new technology" during the past decade. In recent years, a major focus has been the question of equity in the distribution of benefits accruing to individual farmers from development programs embracing new technology. The introduction of new technology in agriculture has many short- and long-run implications for the economy in general and for the farm sector in particular. One of the short-run effects is an increase in the incomes of those farmers who adopt new inputs and techniques. But the important aspect is the effect of adoption on the pattern of income distribution among farmers. The precise nature and exact magnitude of this effect is still unknown. This lack of knowledge is important in that it is now increasingly felt that the real farm problem lies not only in the low average incomes in agriculture but also in their unequal distribution among farmers.

This study attempts to measure the farm income inequality in the West Godavari district for the years 1967–68 and 1970–71 and to isolate and measure the net influence of new farm technology on the farm income distribution in the district.[1] The study is restricted to an analysis of the distributional effects of new technology on farm incomes. It does not address the question of factoral distribution effects or distribution effects among consumers and producers. The Intensive Agricultural District Program district of West Godavari was selected because agricultural modernization in such districts has been attempted with relatively more vigor and over a comparatively longer period than in other districts.[2] The data were taken from the Benchmark and Assessment surveys of the IADP district of West Godavari conducted by the Directorate of Economics and Statistics, Ministry of Agriculture, in 1967–68 and 1970–71 (Government of India). The former was selected because it was the year when the impact of new agricultural strategy launched in 1966–67 was having its first impact, and the latter was selected as it was the latest year for which the data were available. A stratified multiple-stage random sample of 400 farmers was selected in the whole district. The district is divided into sixteen community development blocks, which will be the unit of investigation.[3] In each community development block, four to six villages were selected at random, and then in each village eight farmers were selected at random. The sample farmers were interviewed by trained research investigators during both the kharif and rabi seasons each year, and detailed information relating to their farms was obtained.[4]

Findings of Simple Comparisons of Income Distribution

The size distributions of income considered are derived from a classification of the sample farm families on the basis of annual farm income. The data reveal that the average annual income for all the farm families studied in 1967–68 was Rs. 4,079 (rupees). The average income in 1970–71 at current prices was Rs. 8,389. At constant 1967–68 prices, the average income was estimated at Rs. 5,220 (Raju, p. 101). The ordinal ranking of the size distributions is clearly brought out by an analysis presented in table 1. The ninth decile group of farm families claimed about 19% of the aggregate income in 1967–68. The share increased by about 1% in

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[1] West Godavari is a prosperous agricultural coastal deltaic district of the state of Andhra Pradesh in India covering an area of 3,009 square miles. It is situated on the west bank of the Godavari river, which runs through the whole length of the district before falling into the Bay of Bengal.

[2] The Intensive Agricultural District Program (IADP), popularly known as Package Program, was launched in this district in October 1960. The program covered the entire district and involved comprehensive agricultural development in all the major crops in the district (Government of India).

[3] A community development block is the smallest comprehensive developmental unit in the Indian planning structure. Each block covers approximately 100 villages and is supposed to have a full complement of specialists dealing with all technical aspects of agricultural development, plus its own allocation of publicly supplied agricultural inputs such as chemical fertilizers, new seeds, pesticides, credit, etc.

[4] The word "kharif" is used to refer to the monsoon season generally occurring from June through September or early October. The word "rabi" is used for the dry, postmonsoon season, generally occurring from October through January.

Table 1. Relative Shares of Aggregate Income Received by Various Decile Groups of Families in 1967–68 and 1970–71 in West Godavari

	Percentage of Aggregate Income			
Decile Group	1967–68	Cumulative Percentage	1970–71	Cumulative Percentage
First 10%	0.40	0.40	0.52	0.52
Second 10%	0.94	1.34	1.10	1.62
Third 10%	1.48	2.82	1.48	3.10
Fourth 10%	2.14	4.96	2.32	5.42
Fifth 10%	3.28	8.24	3.81	9.23
Sixth 10%	4.91	13.15	5.02	14.25
Seventh 10%	7.49	20.64	8.36	22.61
Eighth 10%	11.28	31.92	13.06	35.67
Ninth 10%	18.69	50.61	19.48	55.15
Tenth 10%	49.39	100.00	44.85	100.00
All groups	100.00	—	100.00	—

1970–71. The highest decile group of farm families claimed about 49% of the aggregate income in 1967–68. Their share reduced to about 45% in 1970–71. The share of the poorest 10% of the farm families increased from 0.40% in 1967–68 to 0.52% in 1970–71.[5] It now remains to see whether the improvement in income distribution was statistically significant.

There are various measures to quantify the difference in inequality between the two distributions. The measures used for this study are: the Gini concentration ratio, the standard deviation of the logarithms of incomes, and the coefficient of variation. These three were selected because they are unaffected by equal proportional increases in all incomes and are sensitive to disproportionate changes at all levels of income. Among the three measures the standard deviation of logarithms of incomes attaches more weight to transfers affecting the lower income classes, the Gini concentration ratio attaches more weight to transfers affecting the middle income classes, and coefficient of variation attaches equal weights to transfers at different levels of income (Atkinson). The most striking feature of the data is that income inequality appears to have fallen from 1967–68 to 1970–71 in the district as a whole in terms of all the three measures (Raju, p. 107). A statistical test was made to determine whether the decline in income inequality from 1967–68 to 1970–71 is significant or not.[6] Based on that statistical test, the null hypothesis that the distribution of farm income in the district for the year 1967–68 is the same as that for the year 1970–71 is rejected at a significant level of 5%. There was a significant decrease in income inequality from 1967–68 to 1970–71 in the district.

There has also been a statistically significant increase in average per farm expenditure for new technology in the district in the period 1967–68 to 1970–71. This increase has been accompanied by a statistically significant decline in the relative variance of the per farm expenditure for new technology (Raju, p. 115). The average area under crops per farm has significantly increased, accompanied by a significant decrease in the relative variance of the cropped area.[7] The average net farm income at current and constant prices in the district recorded a statistically significant increase.[8] The increase in the mean farm income affects farm income inequality according to the position on the income distribution of those whose incomes have increased.

Analysis of the Sources of Changes in Income Inequality

The statistical model used for measuring the net influence on income distribution of selected causal factors is multiple-regression analysis. Assuming that a relationship exists between the farm income inequality Y and the explanatory variables X_1, X_2, X_3, X_4, and X_5, both linear and Cobb-Douglas regression models of the following form were fitted:

$$(1) \quad Y_i = B_0 + B_1X_{1i} + B_2X_{2i} + B_3X_{3i} + B_4X_{4i} + B_5X_{5i}$$

and

$$(2) \quad Y_i = B_0\, X_{1i}^{B_1}\, X_{2i}^{B_2}\, X_{3i}^{B_3}\, X_i^{B_4}\, X_{5i}^{B_5},$$

where Y_i is the income inequality as measured by the standard deviation of the logarithms of the incomes (Y_{1i}), the coefficient of variation (Y_{2i}), and the Gini concentration ratio (Y_{3i}) of the incomes in the ith block; B_j's are the unknown parameters to be estimated ($j = 0, 1, \ldots, 5$); X_{1i} is the relative variance (squared coefficient of variation) of per farm expenditure for improved seeds, fertilizers, plant protection chemicals, and irrigation water in the ith block; X_{2i} is the mean expenditure per farm

[5] The data in table 1 is used to draw the Lorenz curves, and the Lorenz curve of 1970–71 lies above the 1967–68 curve at all points (Raju, p. 105).

[6] F-test is used assuming that income is log-normally distributed with mean μ and variance σ^2 and $\hat{\sigma}_1^2$ and $\hat{\sigma}_2^2$ are dependent and unbiased estimators of σ_1^2 and σ_2^2, respectively. The null hypothesis H_0: $\sigma_1^2 = \sigma_2^2$ is tested against the alternative hypothesis H_1: $\sigma_1^2 \neq \sigma_2^2$, where σ_1^2 and σ_2^2 are the variances of logarithms of the 1967–68 and 1970–71 farm incomes, respectively. The calculated F-value was 1.179 and the critical F is 1.16 at the 5% level. Hence, H_0: $\sigma_1^2 = \sigma_2^2$ is rejected and H_1: $\sigma_1^2 \neq \sigma_2^2$ is accepted.

[7] The mean cropped area per farm was 13.45 acres in 1967–68, and by 1970–71 it is increased to 17.87 acres; the variance of the cropped area is decreased from 1.112 in 1967–68 to 0.955 in 1970–71 (Raju, p. 116). The increase in mean cropped area may be due to the expansion of irrigation facilities, increased use of fertilizers, and introduction of new crop rotations in the district because it has now become possible to grow two or even three crops a year on the same piece of land where only one crop was grown before.

[8] The average farm income in the district recorded a statistically significant increase of about 107% at current prices and 29% at constant prices (Raju, p. 117).

for improved seeds, fertilizers, plant protection chemicals, and irrigation water in the ith block; X_{3i} is the relative variance of the cropped area per farm in the ith block; X_{4i} is the mean cropped area per farm in the ith block; X_{5i} is the mean (log) farm family income in the ith block; and i is 1 to 16 (numbers of blocks).

Theoretically, one could think of a large number of factors that can influence income inequality. If the farm income of a member of a group of farm families is expressed as the sum of the payments to factors of production owned by the member, then income inequality within the group can be analyzed as a function of the relative shares of the factors of production and distribution of factors of production among the members of the group. Besides, any factor that affects either the relative shares of factors of production or the distribution of factors of production or both can also affect income inequality. In this study, only those factors that appear to have special significance in the context of the recent developments in the study area, that is, in the adoption of new agricultural technology such as high yielding varieties of crops, chemical fertilizers, plant protection chemicals, irrigation water, etc., the area brought under multiple cropping and the gross value of farm production are considered.

If the proposition that there is a positive relationship between the level of adoption of new technology and the level of farm income is accepted, then one could expect a similar relationship between inequality in the distribution of income from new technology and inequality in the rates of adoption of new technology.[9] Therefore, the relative variance (squared coefficient of variation) of per farm expenditure for new technology is introduced, and a positive sign for its coefficient is expected. The mean level of per farm expenditure for new technology is also introduced, but since its effect on the distribution of income depends on which group receives more, the sign is undetermined on the theoretical basis.[10] The relative variance of land holdings is expected to have a positive sign, and land holding is the main item in the assets of the farmers. Changes in the mean cropped area again can have a positive or negative effect on the inequality measures, depending on the position of the gains and losses. The mean farm income is included because the increase in the farm income may affect farm income inequality according to the position on the income distribution of those whose incomes have increased. But again, no a priori hypothesis for the sign of the coefficient of this variable can be made.

The regression models are estimated by the method of least squares. Four variants of the regression model are estimated. The first and second variants attempted to explain the block (spatial) differences in farm income inequality for the years 1967–68 and 1970–71, respectively. The third and fourth variants attempted to explain the absolute and relative changes (temporal) in income inequality from 1967–68 to 1970–71, respectively.[11]

Results of Regression Analysis

Table 2 contains the results of all the four variants of the regressions in linear form fitted to explain the spatial and temporal differences in income inequality. The results indicate that, throughout all the four variants and with the three types of dependent variables, the relative variance of the per farm expenditure for new technology (X_1) is the only explanatory variable that has a statistically significant effect on the farm income inequality. However, the level of significance varied among different variants and with different dependent variables. The coefficient obtained the expected sign throughout in all the cases. The implication of this result is that the decrease in income inequality in the district from 1967–68 to 1970–71 was due mainly to a decline in the relative variance of the per farm expenditure for the new technology over the period. This means that a more uniform pattern and level of adoption of new technology among farmers in 1970–71 led to a drop in the farm income inequality in the district. This result may be due to the fact that the period covered the closing phase of an adaption cycle in which selective adoption by early innovaters may first have caused an increase in inequality that was closed as adoption became widespread.

The coefficient of the mean expenditure for new technology (X_2) has a negative sign in most of the cases except for the regression of 1967–68 when the standard deviation of the logs of income and the coefficient of variation are dependent variables and for the 1970–71 regression with Gini concentration ratio. The coefficient is significant only for two variants, that is, absolute and relative changes when the standard deviation of logs of income is the dependent variable. As discussed earlier, the mean expenditure for new technology is expected to have a direct relationship with the income inequality. It is the differential rates of adoption of new technology as characterized by the relative variance of the per farm expenditure for new technology that is directly related to the income inequality. The nature of this indirect relationship between the mean

[9] For instance, adoption of new technology by a subset of farmers can lead to a change in farm income inequality, according to the position in the income distribution of those who adopt. If the adopters are on the lower end of the income distribution, one can expect income inequality to fall and vice versa.

[10] If an increase in the mean level of adoption is accompanied by a decline in the inequality of the rates of adoption brought out by a more than proportionate increase in the ratio of adoption by those at the lower end of the distribution, one could expect a negative coefficient for this variable.

[11] Since the aggregation of the variables included in the model was done at the block level, the total number of observations were equal to the number of blocks in the district. Thus, for each variant there were sixteen observations.

Table 2. Results of the Linear Regressions of Farm Income Inequality

Regression Variant	Regression Coefficients and Their Standard Errors[a]							
	B_0	X_1	X_2	X_3	X_4	X_5	R^2	*F*-Ratio
Taking standard deviation of logarithms of the incomes as dependent variable								
1967–68	0.3886	0.003	0.0001	0.0011	−0.0179	0.3376	0.80	8.01
		(0.0001)	(0.0003)	(0.5500)	(0.0077)	(0.2557)		
1970–71	0.2151	0.0412	−0.0002	0.0752	−0.0066	−0.0880	0.64	3.56
		(0.0125)	(0.0030)	(0.1979)	(0.1176)	(0.2933)		
Absolute change, 1967–68 to 1970–71	0.2205	0.0732	−0.0001	0.0002	0.0103	−0.3783	0.83	3.91
		(0.0404)	(0.00003)	(0.0200)	(0.6241)	(0.2206)		
Relative change, 1967–68 to 1970–71	−2.2555	0.1390	−0.2096	0.0719	−0.7667	3.4682	0.77	6.79
		(0.0767)	(0.0641)	(0.6245)	(0.2829)	(1.7029)		
Taking coefficient of variation as dependent variable								
1967–68	1.1350	0.3642	0.0001	0.0062	−0.0342	−0.0277	0.69	4.66
		(0.1633)	(0.0019)	(0.7025)	(0.0155)	(0.0461)		
1970–71	1.6904	0.2728	−0.0002	0.3339	−0.0272	−0.2497	0.85	12.18
		(0.1228)	(0.0188)	(0.2226)	(0.0112)	(0.3284)		
Absolute change, 1967–68 to 1970–71	0.1236	0.0629	−0.0001	0.0139	−0.0045	0.1094	0.65	3.58
		(0.0347)	(0.0011)	(0.0463)	(0.1666)	(0.0295)		
Relative change, 1967–68 to 1970–71	1.0736	0.6272	0.0252	0.0073	−0.6029	2.0325	0.68	4.25
		(0.2023)	(0.0504)	(0.6083)	(0.2632)	(0.9583)		
Taking Gini concentration ratio as dependent variable								
1967–68	−1.2926	0.2454	−0.0005	0.0206	−0.6663	−0.3164	0.57	2.65
		(0.1355)	(0.1315)	(0.0686)	(1.6572)	(0.4246)		
1970–71	−1.8484	0.3155	0.9001	0.2699	0.0004	−0.0700	0.78	7.46
		(0.0979)	(0.0056)	(0.1533)	(0.0100)	(0.3255)		
Absolute change, 1967–68 to 1970–71	0.1677	0.0231	−0.0001	0.0003	0.0140	−0.4242	0.56	2.54
		(0.0111)	(0.0013)	(0.0300)	(0.0177)	(0.3165)		
Relative change, 1967–68 to 1970–71	−1.3323	0.1854	−0.1081	0.1797	−0.3123	2.5664	0.64	3.56
		(0.1415)	(0.1010)	(0.1144)	(0.5296)	(1.9152)		

Note: Explanatory variables are defined in the text.
[a] Figures in the parentheses are the standard errors of the regression coefficients. No. of observations = 16.

expenditure for new technology and the income inequality depends on the nature of the former's relationship with the relative variance of the per farm expenditure for new technology. Findings in table 2 support this contention because the variables X_1 and X_2 are negatively correlated both across blocks as well as over time, as indicated by zero-order correlation matrices, with X_1 having a positive sign and X_2 showing a negative sign (Raju, p. 185). The coefficient of the relative variance of the cropped area (X_3), which reflects differences in the distribution of the cropped area among the sample farms, has the expected positive sign in all the regressions. But the coefficient is never statistically significant. The coefficient of the per farm cropped area (X_4) has a negative sign and is significant in most of the cases. Finally, the mean level of income (X_5) has a negative coefficient in most of the cases and is not statistically significant in many cases. As the results of the Cobb-Douglas form are more or less similar to those of the linear, they are not presented here.

The results of this study differ with the views of some economists who argue that the stage has not been reached in Indian agriculture in which equality in the rates of adoption of new technology among operators of small and large farms and the resulting income inequality start declining. But in the IADP district of West Godavari, special arrangements for supply of new production inputs and credit and for training and education of farmers in the use of new technology did reduce the early inequality in the rates of adoption of new technology among operators of small and large farms and also the income inequality. The base year, that is, 1967–68, was the year when the impact of the new agricultural strategy launched in 1966–67 was visible on the farm front, that is, early in the adoption cycle of

high yield varieties (HYV's).[12] This changed the level of resource use, and new technology caused an upward shift in the production function, especially for paddy and wheat, thereby increasing farm incomes. Thus, the positive relationship between new technology and farm incomes that started in 1967–68 continued until 1970–71 and beyond. A similar positive relationship between reductions in inequalities in the rates of adoption of new technology and inequalities in the distribution of income from new technology also occurred. The government investment in such infrastructure facilities and other services as tube wells, fertilizers, credit, marketing, extension, and training, etc., in this district enabled all size groups of farmers to benefit from new technology. Since these facilities and services increased both in quality and quantity from 1967–68 to 1970–71, inequality in the rates of adoption of new technology between the small and the big farmers dropped and so did the farm income inequality.

Conclusions

The results of this study suggest two major conclusions. First, the estimates of income inequality indices indicate an overall decline from 1967–68 to 1970–71 in the farm income inequality in the district. Second, the more equal adoption of new farm technology has significantly reduced income inequality. Although the results of the study are based on only two separate crop years of a single district of India, which is a fairly large country, and the district is an IADP area in which the government took more interest than in other areas, the conclusions of this study may serve as a guideline for the following possible implications for policy purpose.[13] The increasing mean levels of farm income associated with the declining farm income inequality in the district over the period 1967–68 to 1970–71 represent a step towards the achievement of a higher level of economic well being for farmers. The introduction of new agricultural technology in the district led to an increase in the economic welfare of the farm people because all income groups were better off in terms of their mean incomes and no group was worse off than before. The results of this research demonstrate a possibility of simultaneously increasing the mean level of income and reducing income inequality. This is what India wants to achieve by means of various agricultural development programs and policies. This conclusion is useful for policymakers who could reduce the unequal distribution of incomes by extending the development programs and policies that are adopted in IADP areas to other areas where the income inequalities are increasing.

The increased incomes are usually associated with increased consumption of material goods and services. This could lead to a short-term conflict between the present consumption level and the investment in new technology. The conflict would be more serious with more equitable distribution of income between the higher income farmers and the lower income farmers because of the latter's higher propensity to consume. However, the increase in the average expenditure for new technology from 1967–68 to 1970–71, accompanied by a decline in the relative variance, seems to indicate that investment in new agricultural technology is not affected adversely. This could be due to a change in the attitude of the farmers who are now becoming increasingly conscious of the need to invest directly in productive activities even if some restraints are imposed on their current consumption. This suggests that a conflict between present consumption and investment in new technology is not inevitable in the process of agricultural development. The substantial increase in the average expenditure for new agricultural technology recorded for the lower income groups in the period 1967–68 to 1970–71 seems to suggest that there is nothing inherent in new technology that makes it suitable for higher income farmers and unsuitable for lower income farmers. This is because the main components of new technology, namely, improved seeds, fertilizers, plant protection chemicals, etc., are all perfectly divisible and could be used in any quantities. Even the services of a tractor, an irrigation pump, or some other improved farm equipment could be hired in.

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[12] HYV's of paddy have been first introduced in this district during 1966–67 in an area of 4,210 acres. The area under HYV has increased to 73,000 acres in kharif season and 137,000 acres in rabi season during 1970–71. At present, there are as many as twenty HYV's of paddy that are being tried (West Godavari, p. 6).

[13] IADP districts are different than other areas where inputs are not evenly distributed.

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A Note on Unemployment and Labor Migration in Less Developed Countries: A Diagrammatic Illustration

Ozay Mehmet

The relevance of economic theory for providing a rational explanation of the unemployment problem of LDC's has long been a topic of controversy (Schultz, Paglin, Hansen, Reynolds, Berry, Horowitz). In particular, in recent years there has been a considerable attention devoted to the perplexing fact of significant rural to urban migration in the face of large urban unemployment (Harris and Todaro).

This note presents a simple two-sector model of unemployment equilibrium in an attempt to offer an economic rationale for this curious fact. The model implies a trade-off process between disguised unemployment in the rural sector and open unemployment in the urban sector.[1] In addition, the note takes explicit and full account of the influence of seasonal fluctuations in farming activities on labor demand and wage determination and the extended family system that performs the dual functions of setting the supply price of labor in the urban sector and giving rise to a system of income maintenance that is financed significantly out of cash remittances from the urban to the rural sector. The importance of the seasonality factor has been recognized in the past (Berg, Elkan) but the role of remittances has been introduced only recently (Mehmet 1971b, Waters). Both the seasonality factor and cash remittances have to be incorporated into any comprehensive model of unemployment equilibrium purporting to explain the labor market mechanism in the LDC's.

The present model assumes a two-sector economy featuring internal trade and factor mobility. There is perfect competition with producers in both sectors behaving as profit maximizers and consumers and workers as utility maximizers. In figure 1, the right-hand quadrant depicts labor market conditions in the urban sector in which wage employment predominates, while the left-hand quadrant refers to the rural sector in which traditional subsistence farming predominates. The extended family system exists throughout the economy. OW_s is the minimum subsistence real wage rate, and it is guaranteed to each and every person within the extended family regardless of individual (marginal) contribution to family income. Therefore, OW_s acts as the minimum supply price of labor in the urban sector. Total labor endowment is equal to M_3N_1, of which OM_3 is in the rural and ON_1 in the urban sectors. Demand for labor in the two sectors are represented by D_rD_r and D_uD_u, the former reflecting off-season demand conditions.

If voluntary migration of labor from the rural to urban sector prompted by real wage differential is assumed, equilibrium conditions in the two labor markets cannot uniquely be determined because the volume of migration cannot a priori be specified. In one extreme case, all of the disguised unemployment might choose to stay in the rural sector. This might happen if the income support system of the extended family is so comprehensive that it effectively defeats incentive and desire for wage employment and economic independence. In the opposite extreme case, all of the disguised unemployed might move to the urban sector in anticipation of higher real income. In the former case, disguised unemployment would equal M_1M_3, with M_1M_2 having marginal product equaling 0 or more (but less than OW_s) and M_2M_3 having negative marginal product. OM_1 amount of labor would be employed receiving minimum subsistence real wages. The corresponding equilibrium in the urban sector would feature ON_1 employment at a real wage rate of OW_1. If we assume the possibility of cash remittances from the urban to the rural sector, channeled through the extended family system, an amount of real income up to $ON_1 \cdot W_sW_1$ might be transmitted to support the disguised unemployed. Whether or not such income transfers would be adequate to raise the average per capita real income in the rural sector to OW_s would depend on the volume of disguised unemployed initially and the slope of the D_uD_u curve. Under normal conditions,

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[1] Disguised unemployment here is defined in the sense of the marginal product being less than the subsistence real wage rate. This definition implies that disguised unemployment consists of two parts, one characterized by negative marginal product and the other characterized by a marginal product equal to or greater than 0 but less than the subsistence real wage rate. This is illustrated in figure 1, in which the first type of disguised unemployment is represented by M_2M_3 and the second by M_1M_2. The present definition tends to overcome the identification problem of whether or not disguised unemployment necessarily implies zero or negative marginal product of labor—a topic of long controversy (Mehmet 1971a).

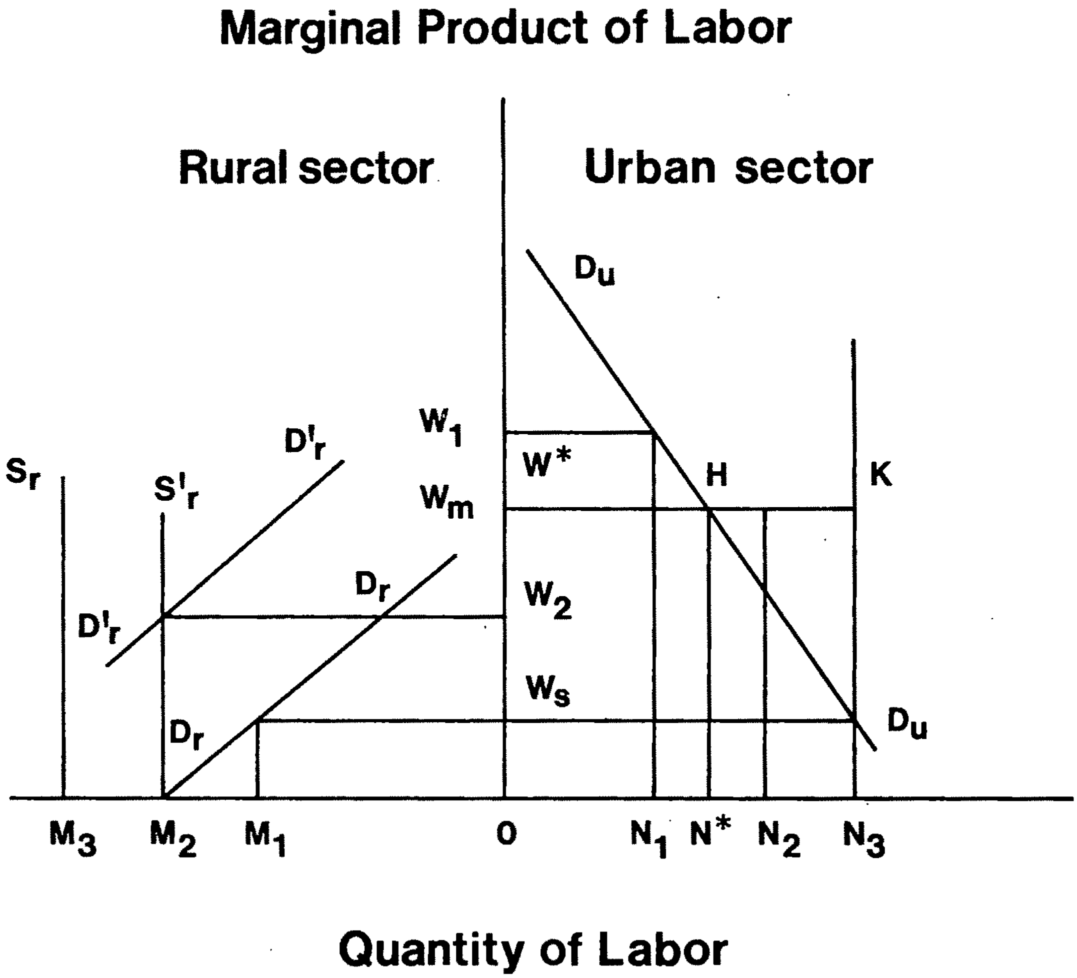

Figure 1. Real wage rate for the two-sector economy

it may be assumed in fact that the average per capita real income is capable of being raised to OW_s.

Given the assumption of rational migration, some of the disguised unemployed would be motivated to move to the urban sector in search of wage employment. So long as the real wage rate offered to them is no less than OW_s, they would be better off by accepting such employment. The limiting case is when all of the disguised unemployed move to the urban sector and a common real wage rate equaling the subsistence wage is established throughout the economy.[2] Thus, if no minimum urban wage rate existed, equilibrium in the urban labor market could be established anywhere between the limits of OW_s and OW_1. Within this range, there would be wage flexibility.

[2] It is assumed that the overall population is not excessive relative to aggregate supply of cooperant resources. If overpopulation existed in this sense, then one could expect strong "push" effects causing international migration or its elimination in the long run through sheer starvation.

Suppose, however, that an urban minimum wage rate, denoted by OW_m in figure 1, is introduced either for political reasons and/or trade-union demands. This would reduce the range of wage flexibility to the distance between W_m and W_1 and thereby effectively preclude the establishment of a common real wage rate OW_s in the extreme case described in the preceding paragraph. The minimum urban wage rate OW_m would create a horizontal supply curve and would be capable of generating excess supply up to a maximum of HK. This maximum is determined by the initial quantity of disguised unemployment in the rural sector, M_1M_3, and reflects the situation in which all of the disguised unemployed migrated to the urban sector: N_1N^* of them would secure employment at the minimum urban wage rate OW_m, while the remainder of HK would become unemployed. Given the minimum urban wage rate OW_m, the only way to achieve a full-employment equilibrium in the urban sector would be to tolerate disguised unemployment in the rural sector. Thus, there is a trade-off

between urban and disguised unemployment underlying the model depicted in figure 1: any equilibrium would entail some type of unemployment such as disguised, urban, or a combination of both. If the minimum urban wage rate were eliminated, wage flexibility could bring about a common wage rate at OW_s ensuring bare subsistence for everyone with OM_1 amount of labor allocated to the rural and ON_3 to the urban sectors. Once wage inflexibility is introduced, some form of unemployment is inevitable. Since the extended family system is assumed to exist throughout the economy, the unemployed would be supported by their employed relations.

The unemployment equilibrium described above is unlikely to persist for any significant length of time because of a unique characteristic of the rural sector, namely, seasonal fluctuations in farming activities associated with planting and harvesting crops during peak seasons followed by periods of slack during off-seasons. Suppose that, immediately prior to the onset of a peak-season, labor allocation between the two sectors is such that there is OM_2 amount of labor in the rural sector, with M_1M_2 volume of disguised unemployed. Then there is ON_2 amount of labor in the urban sector, with N^*N_2 volume of urban unemployment.[3] Suppose, moreover, that the onset of the peak season shifts the demand curve in the rural labor market from D_rD_r to $D_r'D_r'$ *ceteris paribus*. With only OM_2 amount of labor in the rural sector, increased demand would raise the real wage rate from OW_s to OW_2. All the disguised unemployed would now be absorbed in productive employment receiving wages significantly above subsistence level. If it is assumed that part of these additional earnings are reserved for use during the slack season to supplement financial assistance provided out of extended family sources, then one would have a rational explanation for the persistence of disguised unemployment in LDC's based on the seasonality factor coupled with the extended family system.

Indeed, the seasonality factor would offer a rationale for the pattern of temporary labor migration observed in some LDC's. Suppose, for example, that the increase in demand for labor in the rural sector during the peak season is substantial enough to raise the wage rate to OW^* above OW_m. Consequently, all of the unemployed as well as some of the employed persons in the urban sector, acting rationally, would move back into the rural sector attracted by the relatively higher rural real wages.[4] The resulting equilibrium in the urban sector is likely to feature a volume of employment somewhat less than ON^* with a wage rate somewhat higher than OW_m, while the equilibrium in the rural sector is likely to be established at a point corresponding to a volume of employment somewhat larger than OM_2 and a wage rate somewhat less than OW^*. In general, urban-rural migration, conceivable during peak seasons, is parallel to the more usual migration in the opposite direction in that it, too, is motivated by expected higher real earnings.

Once the peak season is over, demand for labor in the rural sector would fall back to D_rD_r, and the forces of change described in the preceding paragraph would operate in reverse direction. This whole process of change and reaction can be expected to be repeated with every seasonal change in the rural sector except, of course, in the event of bad harvests or political instability or other exceptional conditions.

Before drawing any implications from the present analysis for economic policy and planning in LDC's, it is necessary to observe its underlying limitations. There are a number of restrictive assumptions, especially regarding the existence of perfect competition in the two sectors and rational labor mobility between them. In fact, actual conditions in many LDC's are characterized by serious imperfections and rigidities (such as insufficient information about job opportunities, traditional land tenure systems, and cultural values) that adversely affect the pursuit of profit-utility maximization.[5]

Nevertheless, while the marginal conditions of the perfect competition model may not precisely conform to the real world of LDC's, there is growing empirical evidence supporting the view that the rationality principle of the price-market theory is relevant. For example, it is now increasingly being recognized that the smallholder farmer is an efficient economic decisionmaker within the bounds of the scarce resources at his disposal and the uncertainties of his environment and that he will respond positively to take advantage of profitable opportunities (Krishna, Castello, Cohen). Careful studies of the social, institutional, and cultural factors and their impact on the motivations and behavior of traditional farmers in many LDC's are now demonstrating that the alleged resistance of smallholder farmers to innovation is often due to the failure of extension workers and agricultural administrators to offer feasible, low-cost technology that promises satisfactory returns at acceptable levels of risk (Mellor; Johnston, Page, and Warr). Thus, the critical constraints on production appear to be the availability of low-cost agricultural credit to expand the working capital and technical assis-

[3] This is one of the infinitely possible sectorial allocations that can be achieved consistent with the minimum urban wage rate and supply-demand conditions as illustrated in figure 1. OM_2 amount of labor in the rural sector implies that all disguised unemployed initially with negative marginal products (i.e., M_2M_3) migrate to the urban sector where N_1N^* obtain employment at the urban minimum wage rate while N^*N_2 remain unemployed. Recall that $M_2M_3 = N_1N_2$.

[4] This would tend to explain the phenomenon of a sharp rise in absenteeism on plantations and in urban industries during harvesting seasons in dualistic economies.

[5] The model of wage determination in figure 1 can be reformulated by assuming monopsony conditions, for example, in the urban labor market. Such a reformulation would imply that the amount of remittances to the rural sector would be reduced owing to monopoly profits realized by the employer, relative to the competitive model.

tance with regard to fertilizer use, crop cultivation, and marketing, as well as the availability of low-cost farm technology.

In the face of double-digit open unemployed in urban areas of many LDC's (Turnham), it is now timely and necessary to reexamine past development objectives and strategies. In retrospect, it is clear that the postwar policies of industrialization, based on Lewis-type dualistic models, were faulty. These models were based on the concept of draining rural surpluses into nonagricultural sectors. The results in many LDC's have been widening urban-rural disequilibria featuring mounting urban unemployment coexisting with a small, capital-intensive urban sector, typically protected by artificially high tariffs (Little, Scitovsky, and Scott).

The persistence of urban-rural wage differentials, in excess of differences in marginal productivities in the two sectors, implies continued or even increased migration flows, unless remedial policies are effectively introduced. Three potential solutions have been offered. One is the reduction of urban wages by direct government action, but this is unlikely on political grounds (Berry, Smith). The second is the physical control of migration through pass system or labor laws now existing in South Africa and a few other African countries, but this, too, is unlikely to succeed owing to the repressive consequences of the proposal (Harris and Todaro). The third and most promising solution is agricultural and rural development. This is the principal conclusion of the present analysis.

In future planning and policy formulations, agrarian and rural development must be accorded much higher priority. This would be justified on grounds of both greater economic efficiency and equity. Switching development funds into the rural sector is likely to serve the multiple objectives of greater food production, more productive utilization of labor and nonlabor resources, and wider diffusion of the benefit of economic growth across the entire country instead of limiting them to urban sectors, as well as reducing the incentive for rural-urban migration.

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Effects of Tax Depreciation Policy and Investment Incentives on Optimal Equipment Replacement Decisions: Comment

Ronald D. Kay and Edward Rister

The recent article by Chisholm in this *Journal* is a welcome addition to the literature on farm-asset replacement. The effect of income taxes on asset replacement has been largely ignored in the economic analyses of decisionmaking by the farm firm. Yet farmers obviously operate in an environment in which income taxes are an important factor in many of the decisions they make.

Chisholm reported the results of changes in Australian income tax legislation on the optimal replacement time for a capital asset. He also reported that, by applying U.S. income tax regulations to his data, he found an eleven-year optimal replacement policy that was the upper limit on his data. The only exception was for an after-tax discount rate of zero when the indicated replacement age was eight years. These results were reported as being unaffected by the depreciation method used or by including additional first-year depreciation and investment credit in his model.

Chisholm's results were surprising and appear to contradict the replacement patterns followed by U.S. farmers. Many full-time, commercial farmers replace their primary tillage tractors and harvesting equipment well before eleven years. The purpose of this comment is to extend Chisholm's work to another set of data under U.S. income tax regulations and to explore some reasons for the differences in optimal replacement age from that observed on many U.S. farms.

Following Perrin's suggestion (p. 65) that calculating present values for each possible replacement year may be a better procedure than evaluating the marginal criterion, the following model was used assuming all expenses, income tax, and replacement occur at year-end:[1]

$$PV_n = \frac{1}{1-(1+r)^{-n}}\Big\{(C_0 - C_n[1+r]^{-n}) + (1-T)\Big(\sum_{k=1}^{n} R_k[1+r]^{-k}\Big) - T(A_n[1+r]^{-1}) - T\Big(\sum_{k=1}^{n} D_k[1+r]^{-k}\Big) - I_n(1+r)^{-1}\Big\},$$

where PV_n = the present value (cost) of a perpetual replacement policy of n years, r = after-tax discount rate, C_0 = initial cost, C_n = market value at the end of year n in constant dollars, T = income tax rate, R_k = repair cost in year k in constant dollars, A_n = additional first year depreciation that can be taken with a replacement policy of n years, D_k = regular depreciation in year k, and I_n = investment credit that can be taken with a replacement policy of n years. For convenience, the model assumes market value and replacement age are correctly anticipated so terms for recapture of depreciation and investment credit are not needed. The replacement policy that minimizes PV_n is selected as being optimal.

Data for market value and annual repair cost were generated for a wheeled tractor with a new cost of \$15,000. The market value at the end of each year as a percentage of original new cost was estimated from the equation $RV = 65.6 - 4.1X$ using data from a study by Peacock and Brake (p. 5), where X is the tractor's age. Annual repair costs for an assumed constant 800-hour annual use were calculated from a repair cost function developed by Bowers (p. 32). Table 1 shows the year-end market value and annual repair costs in constant dollars for fourteen years.[2]

The results of this analysis are shown in table 2 for selected combinations of after-tax discount rates and tax rates. Several conclusions can be drawn from these results: (*a*) the after-tax discount

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[1] In the computer program written to evaluate the present values, additional first-year depreciation was not permitted until a six-year or longer replacement period was being evaluated and the reduced investment credit tax for a three- to six-year useful life was also included in the program.

[2] If the used machinery market was perfectly competitive, the market value of a used machine would be the net present value of its future earnings. This would cause a decisionmaker to be indifferent towards replacement ages except for the age at which the machine was scrapped. This study follows Chisholm's procedure of conducting a partial equilibrium analysis assuming constant market prices for used tractors.

Table 1. Market Value and Repair Cost Data for $15,000 Tractor

Year	End-of-Year Market Value	Annual Repair Costs
0	$15,000	$ 0
1	9,225	310
2	8,610	566
3	7,995	734
4	7,380	869
5	6,765	985
6	6,150	1,090
7	5,535	1,184
8	4,920	1,273
9	4,305	1,355
10	3,690	1,432
11	3,075	1,506
12	2,460	1,576
13	1,845	1,643
14	1,230	1,707
		$16,230

rate has the greatest effect on optimal replacement policy, (*b*) the tax rate causes only slight differences in optimal replacement policy, (*c*) the depreciation method used has little effect on replacement age, and (*d*) the optimal replacement age is longer than that normally observed to be followed by full-time, commercial farmers, particularly at the higher discount rates. These last two conclusions support Chisholm's results.

However, contrary to Chisholm's results, additional first-year depreciation and particularly investment credit did affect optimal replacement age. With these terms in the model, the optimal replacement age was from one to four years less than without them for the lower discount rates. There was no change for after-tax discount rates greater than 5% and, as would be expected, the differences tended to be larger the higher the tax rate. As can be seen in table 3, investment credit causes most of the change, while using additional first-year depreciation alone in the model tended to lengthen the optimal replacement age in the 50% tax bracket.

We were also unable to verify Chisholm's results as presented in his table 2 for the U.S. income tax situation at the 5% discount rate. A possible explanation for this is that in calculating the investment credit that can be taken on a tax-free exchange of an used asset for a new one, Chisholm may have made an error. It is commonly assumed that investment credit can be taken only on the cash difference or "boot" on such a trade. However, Treasury Regulation Section 1.46-3(c)(1) permits investment credit to be taken on the cash difference plus the adjusted tax basis on the used asset traded in (i.e., on the beginning tax basis of the new asset). Chisholm's results appear to be correct when investment credit is taken only on the cash difference on a trade-in. This same error may account for the different conclusions on the effects of investment credit on optimal replacement age.

A major factor in determining replacement age in the model is the pattern of repair costs. If the pattern of repair costs experienced by farmers is different than the one used here, it may explain some of the difference in the theoretical replacement age calculated here and the actual replacement policy followed by farmers. Annual repair costs calculated using Bowers's equation increase at a decreasing rate. To test the effect of another repair cost function, one was generated with annual repairs increasing at an increasing rate but with the total repair cost remaining at $16,230. This repair function caused as much as a five-year change in the optimal replacement policy with the largest changes occurring with discount rates of 4% to 6%. Optimal replacement age was seven or eight years for after-tax discount rates of 0 and 1% and increased with the discount rate to become twelve or fourteen years at a 15% discount rate. Again, these results were affected little by tax rate or depreciation method used.

One of the factors contributing to the long replacement interval is the rapid depreciation during the first year. The nearly 40% loss in market value the first year represents a major cost to be borne by an early replacement policy. Other factors that would be expected to lengthen the replacement age are the income tax regulations that require a useful life of six years or longer before additional first-year depreciation can be taken and seven years for the full 7% investment credit.

The differences in present value (cost) for different replacement ages were small in many instances. This indicates a small cost associated with a "too early" replacement policy. A factor that would help justify and explain a shorter replacement policy is reliability. Realistically, as a machine ages, there is an increasing probability of a

Table 2. Optimal Replacement Age in Years

Tax Rate (%)	After-Tax Discount Rate (%)	Depreciation Method: Straight Line	Depreciation Method: Double-Declining Balance
0	0	9	9
0	1	10	10
0	3	11	11
0	5	14	14
0	10	14	14
25	0	8	8
25	1	9	9
25	3	11	11
25	5	14	13
25	10	14	14
50	0	7	7
50	1	8	8
50	3	12	11
50	5	14	13
50	10	14	14

Table 3. Present Value (Cost) under Selected Tax Policies*

Tax Rate (%)	Discount Rate (%)	S/L Depreciation Only	DDB Depreciation Only	DDB Depreciation Plus AFYD	DDB Depreciation Plus InvCr	DDB Depreciation Plus AFYD and InvCr
0	1	219,759 (11)	219,759 (11)	219,759 (11)	209,156 (10)	209,156 (10)
0	3	78,886 (13)	78,886 (13)	78,886 (13)	75,509 (11)	75,509 (11)
0	5	50,651 (14)	50,651 (14)	50,651 (14)	48,631 (14)	48,631 (14)
0	10	29,974 (14)	29,974 (14)	29,974 (14)	28,679 (14)	28,679 (14)
25	1	167,241 (11)	166,556 (11)	166,369 (11)	155,684 (11)	155,550 (9)
25	3	61,450 (14)	60,934 (13)	60,686 (13)	57,509 (11)	57,316 (11)
25	5	40,334 (14)	39,838 (14)	39,565 (14)	37,795 (13)	37,541 (13)
25	10	25,002 (14)	24,513 (14)	24,225 (14)	23,217 (14)	22,929 (14)
50	1	114,663 (12)	113,354 (11)	112,964 (12)	102,053 (8)	101,831 (8)
50	3	43,992 (14)	42,981 (13)	42,468 (14)	39,478 (10)	39,123 (11)
50	5	30,016 (14)	29,025 (14)	28,478 (14)	26,904 (12)	26,433 (13)
50	10	20,030 (14)	19,052 (14)	18,476 (14)	17,756 (14)	17,180 (14)

* At the optimal replacement years shown in parentheses.

breakdown or a loss in reliability causing not only increasing repair costs but costs resulting from a loss of timeliness. The cost of a delay in planting or harvesting may be substantial and may have an impact on the replacement decision. If farmers view this loss of reliability as a cost, it would help explain a replacement policy more rapid than that calculated here.

We could find no data on breakdown probabilities as a function of age or a reliable measure of the resulting loss. To illustrate the possible effects of a loss in reliability, a hypothetical set of probabilities were developed that increased at an increasing rate with age. A constant nonrepair cost was assumed for each breakdown with the resulting "reliability loss function" going from $47 in year 1 to $2,345 in year 14. The results from including these costs in the model are shown in table 4. Reductions in the optimal replacement age were much greater, particularly at the higher discount rates, than for any other modification of the basic model that we tried. The dominant seven-year replacement age indicates that the investment credit eligibility rules may have had some influence in this case.

While the tax regulations that permit using double-declining balance depreciation and taking additional first-year depreciation and investment credit did not have as large an effect on optimal replacement age as might be expected, they did affect the present value (cost) of obtaining the constant annual stream of tractor services. The values for selected tax-rate–discount-rate combinations under various tax regulations are shown in table 3. The effect of these tax regulations is to lower the present value (cost) of any replacement policy. This result has probably, in part, encouraged the trend towards larger equipment and the substitution of machinery for labor. The net result is a larger overall investment in farm machinery than would have existed without these incentives.

To test the effect of lowering the useful life required by income tax regulations for assets to be eligible for additional first-year depreciation and investment credit, results were obtained for the case in which both deductions could be taken in full with a three-year useful life. There was no change in the optimal replacement age when compared to those calculated under the current eligibility rules. However, an increase in the investment credit rate does reduce the optimal replacement age. Using the 10% rate permitted in 1975 and 1976 caused a one- or two-year reduction in the replacement age for after-tax discount rates of 5% or less when using double-declining balance depreciation.[3]

[3] A change in the income tax regulations may also affect the

Table 4. Effects of an Increase in Cost Due to a Loss in Reliability on Optimal Replacement Age

Tax Rate (%)	After-Tax Discount Rate (%)	Basic Model W/DDB Depreciation	With "Reliability" Cost Added
0	0	9	7
0	1	10	7
0	3	11	7
0	5	14	7
0	10	14	7
0	15	14	8
25	0	8	7
25	1	9	7
25	3	11	7
25	5	13	7
25	10	14	7
25	15	14	9
50	0	7	7
50	1	8	7
50	3	11	7
50	5	13	7
50	10	14	8
50	15	14	10

A U.S. tax policy that permits double-declining balance depreciation, an additional first-year depreciation, and investment credit for farm equipment has encouraged some changes in optimal replacement age with the amount of change depending on the tax bracket and after-tax discount rate. However, the optimal replacement ages from the model are longer than observed on many farms, indicating that there are factors not included in the model that affect farmers' replacement decisions. Some possible explanations are: (*a*) a repair cost pattern that is different than either considered in this study, (*b*) the loss in reliability as a machine ages, (*c*) the desire or need to replace earlier with a larger machine, and (*d*) a desire to replace earlier in order to utilize the improved technology incorporated in the replacement.

Technology has continued to improve the capacity, efficiency, convenience, and operator comfort incorporated in farm equipment. These continual technological improvements likely contribute also to a shorter replacement policy. When the authors showed the early results of this study to a farmer and then asked him why he traded tractors at a much earlier age, his immediate response was "because the new one is always better."

market values of used machinery. The net effect may be little or no change in the optimal replacement age.

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Effects of Tax Depreciation Policy and Investment Incentives on Optimal Equipment Replacement Decisions: Reply

Anthony H. Chisholm

The central concern of my paper was to develop a replacement model that incorporated the effects of income tax policy and to apply the model to a case study of the effects of Australian income tax regulations on optimal tractor replacement ages. On the basis of a considerably more restricted application of my model, I concluded that U.S. income tax regulations would not appear to influence significantly the optimal timing of replacement.

In their comment, Kay and Rister seek to extend my work by undertaking a more extensive empirical analysis of the effects on replacement of the U.S. income tax regulations. Employing a present value model similar to relation (3) in my paper (p. 777) but using another set of data, Kay and Rister find that contrary to my results at lower discount rates (≤ 5%) the U.S. investment credit lowers the optimal replacement age. In addition, they were unable to verify my result in table 2 for the U.S. income tax situation at a 5% discount rate. The reason for being unable to verify this result is due to a small calculation error in my paper. The optimal replacement age at the 5% discount rate should be eight years (annuity cost $500) and not eleven years (annuity cost $502). I did not make the error suggested by Kay and Rister, namely, to assume that the investment credit can be taken only on the cash difference or "boot" on a trade in.

That the U.S. investment credit introduces a potential bias towards earlier replacement once an asset has been held for seven years is beyond dispute. The bias is attributable to the fact that the annuity value of the investment credit progressively decreases from the seventh year onwards, i.e., from the first year in which the full investment credit may be claimed. This is clearly illustrated in my table 3 in which annuity values for the U.S. investment credit and for various depreciation methods (relative to a neutral depreciation allowance) were presented.

My reason for concluding that the U.S. income tax regulations would not appear to influence significantly the optimal timing of replacement is that the bias introduced by the investment credit is very small both in absolute terms and as compared with the former Australian investment allowance. That is to say, for the U.S. investment credit, the absolute differences between annuity values for different replacement ages are comparatively small. The annuity values presented in table 1 illustrate this point. These annuity values, taken largely from table 3 in my original paper, were calculated using a 10% rate of discount. The figures clearly illustrate the relatively small replacement bias of the U.S. investment credit as compared with that of the former Australian investment allowance. For farmers in high tax brackets, the bias of the latter was of sufficient magnitude to make tractor replacement at age one year optimal, as against an eleven-year optimal replacement age for farmers in low tax brackets. The impact on replacement of the U.S. investment credit would be substantially increased if, like the former Australian investment allowance, it could be claimed in full regardless of the age at which an asset was replaced, as is shown by the annuity values in the right-hand side column of table 1. Unlike the investment allowance, however, the incentive towards early replacement provided by the investment credit is independent of a farmer's tax bracket providing, of course, that a farmer has positive tax payments from which to deduct the credit. It is especially important in these circumstances to keep in mind the partial equilibrium nature of the analysis. Initial substantial incentives towards early replacement would be at least partially countered by adjustments in the structure of secondhand tractor prices if current eligibility restrictions on the U.S. investment credit, relating to asset age at time of replacement, were to be completely removed.

To this point I have not discussed the effects of different methods of depreciation on the timing of optimal replacement because both my results and those of Kay and Rister indicate that these effects are fairly minimal. The results in table 1 show that, as compared with neutral depreciation, the former Australian accelerated depreciation allowance has a bias towards later replacement, but for my data the bias was too small to alter the optimal replacement age. Kay and Rister found that the U.S. additional first-year depreciation alone also induces a small bias toward later replacement and that for their data the optimal replacement age was in fact lengthened in the 50% tax bracket.

Finally, Kay and Rister state that the optimal

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Table 1. Annuity Values ($)

Replace at End of Year	Former Australian Investment Allowance	Former Australian Accelerated Depreciation (Relative to Neutral Depreciation)	U.S. Investment Credit (1974)	Investment Credit Without Age Restrictions
1	620	0	—	217
2	287	1	—	114
3	192	12	26	79
4	144	26	21	62
5	116	40	35	52
6	97	56	30	45
7	84	64	40	40
8	74	70	37	37
9	66	73	34	34
10	60	75	32	32
11	54	75	30	30

replacement ages from their model are longer than those actually observed on many farms and give several possible explanations. They suggest that the desire to replace earlier in order to utilize the improved technology incorporated in the replacement may be the most important factor. Although I did not make any attempt to discuss these issues in my paper, there are some indications from farmer surveys that in Australia the risk of breakdown (loss in reliability as a machine ages) is a more important factor influencing earlier machine replacement than the technological improvements incorporated in new models.

[*Received December 1975.*]

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Chisholm, A. H. "Effects of Tax Depreciation Policy and Investment Incentives on Optimal Equipment Replacement Decisions." *Amer. J. Agr. Econ.* 56 (1974):776–83.

Books Reviewed

Buse, Rueben C., and Daniel W. Bromley. ***Applied Economics, Resource Allocation in Rural America.*** **Ames: Iowa State University Press, 1975, x + 623 pp., price unknown.**

This book was designed as an introductory text in agricultural economics with special emphasis on the development of microtheory and its application to rural problems. It contains a descriptive or perspective section. The microtheory section includes production and cost principles, market price determination, comparative advantage, and market structure. The final section is a discussion of rural economic problem areas including low farm income, rural poverty, community development, the agribusiness sector, and natural resource economics. A considerable amount of descriptive material is included in the text, as well as a considerable amount of microtheory.

The text will be well received by students from the point of view of the clarity of presentation, the inclusion of easy-to-understand definitions, and the sizable amount of data included in the book. They may find some parts of the presentation a bit dry, as the authors attempt to obtain completeness of coverage by touching on more than just the central factors involved with the topics of the text.

The material included in the text seems wisely chosen. It has a wide relevance to students with a broad interest in agricultural economics, and important topics have received attention and analysis. At points some teachers will feel that the text has gone into more depth and detail than would normally be expected of students in a beginning course in rural microanalysis. This is not a serious matter, however, because a professor need not assign every page of the text.

Teachers will appreciate this text particularly because of the analytical approach taken to the several topics for consideration in depth. This is probably the greatest contribution of this text to the university student. However, an even greater focus on economic policy issues could have reinforced the learning of the economic principles and brought increased understanding to policy development.

The text is well written, easy to understand, and will fit the needs of a great many college classrooms. As is true with most textbooks in this area, the amount of material that professors will ask their students to read from it may nearly overwhelm them.

I would have liked to have seen an even greater integration of the development of economic principles with their application to real world problems. Even though there is a good deal of application of economic theory to solving important problems in the text, often this application and the development of the theory are many pages apart.

The timing of the printing of this textbook and a basic change in the market and income situation of American farmers is unfortunate. Even though this text is published in 1975, the farm-policy section and the farm-production data are all from a 1972 perspective, focusing on overproduction and low income. Today's students will find this section of the text quite dated. However, the challenge of the classroom teacher is to bring the material up to date, and with such a rapidly changing situation we cannot criticize the text too much for being born at the moment of a dramatic economic change.

The textbook has obviously been prepared with a great deal of care and thought. Particularly appreciated are the annotations in the reference section at the end of each chapter, giving a better idea of the nature of the potential contribution of this reference to the student's understanding.

As a complement to their text, Buse has prepared an accompanying "Study Guide for Applied Micro Economics." This study guide contains helpful introductory material in each of the areas covered and several questions to test comprehension. The answers to all questions are contained in the final pages of the guide. This study guide is particularly well done. It does not correspond in topic coverage directly with the text. The comparative advantage section is superb. The study guide is the best that I have seen, and if its emphasis is consistent with course objectives it would be a boon to understanding.

This text deserves serious consideration on the part of most teachers of introductory agricultural economics in the nation's universities and junior colleges.

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Gulland, J. A. ***The Management of Marine Fisheries.*** **Seattle: University of Washington Press, 1974, vii + 198 pp., $18.50.**

With the third law of the Sea Conference methodically moving coastal fishery controls to 200 miles and with the World Food Conference concerned about food resources, this is a very timely book. Gulland is well respected in the fisheries management field, having written many articles, papers, and books in that area since 1956. He worked for a number of years at the Fisheries Laboratory in Lowestoft, England, where he specialized in population dynamics. He has been concerned with providing scientific advice to various international

commissions such as the Northeast Atlantic Fisheries Commission, the International Commission for the Northwest Atlantic Fisheries, and the International Whaling Commission. Since 1966 Gulland has been in the Fisheries Economics and Institutions Division, Department of Fisheries, Food and Agriculture Organization of the United Nations.

Gulland's experiences and interests are clearly reflected in this book. There is an excellent chapter on Antarctic whaling that runs for twenty-eight pages and another chapter on North Atlantic trawl fisheries that consists of thirty pages.

For the newcomer to fisheries, there is an excellent chapter on the biological basis of management that helps the reader to understand terminology that is traditionally used by marine biologists. Although Gulland's early training was in mathematics, this chapter is understandable to anyone with a knowledge of algebra. While several very complicated mathematical models have been developed to describe fishery population dynamics, Gulland does not use them because the quality of the data available is usually so poor that the models based on these data may only vaguely resemble reality.

One cannot directly determine inventories in fisheries as one can in forestry or farming, where one can see or count the size and number of trees, acres of land, or cattle of feed. The quantity of fish, or the "biomass," is estimated from the relation of total catch to total fishing effort—catch per unit effort. Gulland's discussion on the critical need in fisheries management for adequate data on fishing effort needs to be emphasized.

Historically, the objectives in fisheries management have been quite different from those in agriculture. In fisheries the most widely used objective is the goal of maximum sustainable yield, which Gulland defines as the greatest physical yield that the stock can produce year after year (p. 107). Gulland does recognize that maximum net economic yield or maximum rent are alternative fishery management objectives that have been proposed by Crutchfield and Zellner, Christy and Scott, and Crutchfield and Pontecorvo. While Gulland does mention optimum management strategy, nowhere does he mention "optimum yield" as an objective that is currently being discussed in the National Marine Fisheries Service and state fishery management agencies. To the reviewer, this chapter—the fifth—is by far the most interesting one in the book and should have been the second chapter because of the need to understand the objectives of fisheries management early in the book.

There is a good review of the techniques of fisheries management now in use. There was, however, no discussion of alternative methods such as pricing or landing fees and subsidies that are under consideration. With only a few exceptions, the present management techniques have not prevented the sequential overfishing of the most valuable fishery stocks.

Multispecies fisheries and separate fisheries on different stocks in the same area that interact are reality. Yet nearly all of this book is based on individual species models. Gulland recognizes this when he says "to an excessive degree the methods consider the individual species in isolation, without considering the entire eco-system in which they live" (p. 184).

Gulland is also concerned that international fisheries management will not advance rapidly until there are people "familiar with the biological complexities of the life of fish in the sea, and having the mathematical dexterity to carry out the necessary quantitative analyses" (p. 185). An understanding of microeconomics and industry economics needs to be added to these requirements.

The management of marine resources is a problem of allocation—the allocation of scarce valuable resources to people who are competing for them. Only once does Gulland recognize that these fishery resources are beginning to have value while they are still in the water (p. 189). Until management schemes are developed that deal with the value of these resources and do not treat them as "spoils," there shall be conflicts and problems in fisheries management.

For anyone working in international fisheries management, a review of chapter 7 is essential. In table 8 there is a listing of the international bodies concerned with fisheries management, with acronyms, 1972 membership, date established and auspices, headquarters, eligibility for membership, area of competence, resources covered, and functions. This would be useful as a ready reference.

This is a very readable book on a very interesting subject. Graduate students looking for some challenging and timely subjects would find this book and area worthwhile.

There are both an excellent list of references at the end of each chapter and author and subject indexes.

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U.S. Department of Commerce

Lele, Uma. *The Design of Rural Development: Lessons from Africa.* Baltimore: Johns Hopkins University Press, 1975, xiii + 246 pp., $12.00.

This study commissioned by the International Bank for Reconstruction and Development is designed to be a sequel to the earlier Bank-sponsored study by John C. de Wilde, *Experiences with Agricultural Development in Tropical Africa*, published by Johns Hopkins University Press in 1967 in two volumes. It differs from the earlier study in focus in that much more attention is given to equity questions and problems of increasing income of the lowest income groups.

The study is based on seventeen rural development projects located in seven tropical African

countries: Mali, Cameroon, and Nigeria in western Africa, and Ethiopia, Kenya, Malawi, and Tanzania in eastern and central Africa. These projects and agencies that come up in assessing their performance generate over seventy acronyms that make the text tedious. Fortunately, a glossary of acronyms is provided.

There are two chapters on the characteristics of small farmers in tropical Africa, a chapter on agricultural extension and mass participation, one each on agricultural credit, marketing, social services, and training programs, and two on rural development planning and administration.

The book's major weakness is that because of the author's relatively shallow experience in Africa she misses much of the relevant literature. Yet the book makes a contribution. Just the experience generated from the seventeen projects reviewed yields many conclusions that, while not new, can bear further emphasis. This reviewer can only applaud the conclusion that development programs in Africa are "often based on inadequate knowledge of technical possibilities and their suitability to small-farm conditions" (p. 176). Or that development projects in Africa suffer badly "from poor knowledge of the socio-cultural and institutional environment" (p. 176). There are several short segments of chapters that provide important new data. Here, three pages in an early chapter on labor bottlenecks are particularly noteworthy, as are a page and a half in the same chapter on the sex division of labor and the role of women and two pages farther on in the text on the neglect of women by agricultural extension services in Africa. There is also a good brief discussion of the contribution and problems of tractors and ox plows among small farmers in tropical Africa.

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Maynes, E. Scott. *Decision-Making for Consumers, A Guide to Consumer Economics.* New York: Macmillian Publishing Co., forthcoming.

Maynes has set out to write an introductory text for undergraduate students that emphasizes principles. He has chosen to avoid presenting historical data or facts that will quickly date his writings. He indicates in his preface that illustrations and examples of situations will be used to help the reader retain and reinforce the principles discussed. His objective is to help the student understand relationships between the broad economic principles that affect individual purchase decisions and the performance of the economy. The majority of the book (about 340 pp.) is devoted to individual purchase decisions and how consumers can more effectively satisfy their needs. The final section is concerned with consumer sovereignty. It embraces an overview of the issues (chap. 9), views of economists (chap. 10), and a critique of consumerists (chap. 11).

This book should be given serious consideration as an introductory text. Its readability and examples are major strengths. The initial chapters are a refreshing approach to the benefits derived by individuals who carefully search for and use information to choose among alternatives. His documentation of the value of a dollar saved should generate enthusiasm for the subject matter.

Maynes's second chapter introduces the use of microeconomic concepts for consumer use. The discussion of mental capital (memories) along with subjective and objective costs of searching for information as they relate to consumer payoffs is well done. He then develops the concept of marginality as a practical guide to consumers. The discussion of reasons why consumers fail to use information is good. A brief explanation of retailer ignorance would increase the objectivity of this discussion. My only concern is with his comment that economic theory must be modified to be more realistic and understandable to consumers. In fact, the theory is not "modified." The explanation and application to individuals versus firms or industries may be a modification of traditional presentations, but the principles endure. In fact, Maynes projects a cynical posture towards economics, economists, and business that pervades each chapter. Perhaps it is ego defense, but this seems unnecessary and even counterproductive.

Chapter 4, on acquisition and evaluation of consumer information, would benefit from the recognition of imperfect knowledge of individuals in various levels of the market channel. He implies sellers have complete knowledge and consumers are helpless to defend themselves. Many sellers are at least as ignorant about products and competitors as consumers. This chapter contains a section written by David Gardner concerning deception in advertising, which is very provocative. Unfortunately, it may be too advanced for the beginning student.

Maynes probably views chapter 3, "Product Quality: Meaning, Measurement, and Implications," as his major contribution. His discussion of critical scores and weights as a measure of quality is good. The section concerned with prices and quality is effective. He concludes that his example of a perfect information frontier (lowest price for a given quality level) also illustrates the effect of number of competitors on price. Although one would logically agree with the generalization that intensive retailer competition should be expected to result in the lowest prices possible, his empirical illustration contains evidence of one and two sellers on the perfect information frontier.

"Product Testing and Consumers Union," chapter 5, makes a clear plea for the use of their services. One expects to find an application blank at the end of the chapter. Maynes's long affiliation with Consumers Union is clearly stated, so this chapter is not only appropriate but expected.

Chapters 6 and 7 provide many helpful ideas to improve one's art of negotiating and use of decision

rules. The cases illustrate problems as well as success and should prove practical to nearly anyone. "Individual Redress: The Righting of Consumer Grievances," chapter 8, emphasizes what individuals can do to prevent grievances. In addition, practical guides for redress and appropriate cautions are presented. He illustrates that one should not expect to be successful with all attempts even if his position is correct.

The final section dealing with consumer sovereignty is an objective treatment of issues and alternative views of economists. The book was reviewed in draft form, and the final chapter was not available. Presumably, it will add to the cohesiveness of the first two chapters of this section and lead the reader to a set of conclusions. In fact, one acquires the feeling that he is being prepared for such a climax.

In summary, it is an interesting book for consumers to use to help them better their position in the market place. An intensive knowledge of economic principles is not required. It is not intended as an economics of consumption text. Maynes focuses on his objectives and provides the reader with the guide he promised. An experienced teacher with a sound economics background could use the text effectively. If the instructor lacked a sound economics background, students may develop an unfairly critical view of economics.

William J. Vastine
Texas A&M University

Montgomery, John D. *Technology and Civic Life: Making and Implementing Development Decisions.* Cambridge, Massachusetts, and London: The MIT Press, 1974, 239 pp., $12.50.

It is difficult to argue with Montgomery's central point that policies set by the governments in most less developed countries must "devolve" so that most development programs are administered nearer the local scene to a greater degree than is presently the case. As a corollary, local participation must figure crucially in the decisionmaking process. Community support, we have long known, is more easily won in that manner, and it makes easier the acceptance of useful new ideas and practices. Also, even centrally stationed functionaries then become aware of local problems and needs. Nothing is more discouraging to see than the waste and human suffering involved in a large, centrally organized country with a primary capital city (or even large state capitals) where vaccines arrive after the epidemic, fertilizer after planting when side-dressing will not do, food after the plague, and bales of hay after cattle have already died from lack of feed. Equally disconcerting is the developer (be he a national or a foreigner) who arrives with a perfectly acceptable "cure" that might well work because it fits in with the local mores, but he is ignorant of them and fails to use them. (Some of these practices and beliefs are inadequate to the task, of course.) All of us involved in development work have our shocking stories of development failure, and one only hopes (probably in vain) that there are not too many.

Montgomery sets forth an admirable goal for development administrators when he says that "*modernizing the behavior of citizens* [is] . . . *a primary task of development administration*" (his emphasis, p. 82). The major contribution Montgomery would like to make in this monograph is expressed in this sentence: "Operations designed to change mass public behavior . . . are likely to be better performed, better understood, and more clearly integrated to local needs if the function is delegated to the lowest levels at which they can be conducted and personnel are drawn from a local base whenever possible" (pp. 77–78). He mentions the panchayat as an example. But Montgomery is realistic in saying that third world villages, as many third world countries, are not necessarily democratic (p. 95). (He knows the "local participation" in his scheme is not foolproof!)

Early in the book he takes us first on what seems to me an unnecessarily long and detailed discussion of Western development. Again, I find myself in agreement with Montgomery's central point, but I wish he had stated it more succinctly. What I hear him saying in this section of the book is simply that the "process competition" that characterized development in the west will repeat itself in the third world only at great peril, human suffering, and social unrest. "The means for protecting citizens against these traditional forms of exploitation constitute one of the principal concerns of democratic theory" (p. 93).

The readers of this journal particularly will appreciate this quote referring to U.S. and western technology in LDC's:

> New industrial processes close old factories, or at least displace elements of the work force unable to master them. In agriculture as well as industry, new processes often require investment that is out of the reach of smaller or less prosperous competitors, and the consequences of technological advance may therefore be farm foreclosures, retreat to the crowded cities, and corporate farming (p. 89).

To Montgomery, the results of incidents like this are clearly "widespread social losses, to say nothing of strikes and lockouts, sabotage, and various forms of terrorism" (p. 91). He argues that society may well have to use violence to minimize the public cost of such conflict, but he suggests "not so much responsive violence [Is this a euphemism for "repression"?], which only enhances the social loss, as better intelligence, more adequate forms of negotiation, and more sensitive political processes" (p. 91). I hope this latter optimism is in the realm of the art of the possible, but I wish I could

write as sanguine a prognostication, however tentative.

I would recommend that the reader first work through chapter 6 to see where Montgomery's arguments are leading. He believes in development progress (peasant participation) as a "first-order decision"; this will work with relative smoothness only if there is a technological "fit." The literature is quite complete, if not redundant, on "choice of technology," and we need not belabor it. But it is interesting to hear a distinguished political scientist phrase it in this manner, "technologies can be said to possess their maximum developmental potential when they are designed to offer to large and identifiable citizen groups new standards, new opportunities for investment, and new means of integrating competitive private interests with public interests" (p. 192).

The "second-order decision" (p. 203) is unrealistic to me: "choice of implementing agency." Here, I think Montgomery is in more intellectual and practical trouble. I know that political structures in many LDC's to which he refers are not committed to the kind of participatory change Montgomery advocates; ruling elites—except in very unusual circumstances—are not committed to strengthening the group that threatens their supremacy. Montgomery runs down a list of possibilities, obviously to convince us that this problem can be circumvented. Maybe lower echelon administrators with more contact with those who desire change can do the job? Perhaps public industrial enterprises with less government connection can promote more participation? Could the civil service (presumably lower level), cooperatives organized by the agricultural ministries, or voluntary organizations do the task? And there are more examples. He claims "reliance on traditional government agencies for development purposes seems to be going out of style" (p. 207). I do not happen to think he is correct. In fact, I think he is dead wrong. Planning bureaucracies, Ministries of Agriculture, Departments of Exchequer, etc., are very much under the thumb of the central government; by definition, they are its administrative organs and do its bidding. The public official, however low level, who steps out of line to promote something the government does not want—such as a complete change of social structure—will be affected by raises and promotions and hiring-and-firing decisions emanating from the center of the agency, not from the peasant or peasant groups. True, there are mavericks in any agency. But their influence is marginal at best. Charismatic leaders from this group who promote radical change are probably even more rare.

His "third-order decision" is that of providing incentives, something with which few of us would quibble and with which I will spend no more time.

I cannot leave this generally favorable review without severely criticizing Montgomery's analysis of land reform on pages 72–73: "A study of 25 major land reform efforts that took place in the twentieth century showed that in 16 cases the governments succeeded in improving the security of the peasants' tenure, but only 11 increased their income, and only 9 enhanced their political power" (p. 72). How can we compare Japan's and Taiwan's long-standing reforms that had all of their countries' infrastructure in place at the time of reform with Bolivia's comparatively new reform (1953), Bolivia being an exceedingly poor enclave country that had practically no overhead capital at the time of reform and still has little (although living standards have gone up somewhat)? What about Mexico, a country that created a land reform and proceeded to pour most of its public (and private) funds into the nonreform sector? And to say that Indonesia, Colombia, Brazil, West Pakistan, Ecuador, and Guatemala have had a reform is folly indeed.

I agree that decentralization must be a precondition of any agrarian reform. Certainly, it is the one way to have any hope of the reform being successful. But let us not give credit where it is not due.

This book is well worth having in your library.

William C. Thiesenhusen
University of Wisconsin

Books Received

Boyce, James K., and Robert E. Evenson. *Agricultural Research & Extension Programs.* New York: Agricultural Development Council, 1975, vii + 229 pp., $4.50.

Erb, Guy F., and Valeriana Kallab. *Beyond Dependency The Developing World Speaks Out.* New York: Praeger Publishers, 1975, xii + 238 pp; $15.00, $3.95 paper.

Glantz, Michael H. *The Politics of Natural Disaster.* New York: Praeger Publishers, 1976, xix + 340 pp., price unknown.

Hanumantha, Rao C. H. *Technological Change and Distribution of Gains in Indian Agriculture.* Delhi: Institute of Economic Growth, 1975, xiv + 249 pp., price unknown.

Havlicek, Joseph, Jr. *Selected Matrix Topics for Economists.* Virginia: Virginia Polytechnic Institute and State University, 1974, iv + 176 pp., $5.00.

Looney, Robert E. *Income Distribution Policies and Economic Growth in Semi-industrialized Countries: A Comparative Study of Iran, Mexico, Brazil, and South Korea.* New York: Praeger Publishers, 1975, xi + 196 pp., price unknown.

Mann, Kellogg Charles. *Tobacco: The Ants and the Elephants.* Utah: Olympus Publishing Co., 1975, 176 pp., $8.95.

Neuberger, Egon, and William Duffy. *Comparative Economic Systems: A Decision-Making Approach.* Boston: Allyn and Bacon, 1976, vi + 378 pp., price unknown.

Parker, William N., and Eric L. Jones. *European Peasants and Their Markets.* New Jersey: Princeton University Press, 1975, viii + 366 pp., $16.50.

Pohoryles, Samuel, Arieh L. Szeskin, Micha Gisser, and Emanuel Dlayahu. *Agricultural Adjustment In Semi-Arid Areas: Case Study—Israel.* Tel-Aviv: Ministry of Agriculture, 1975, xxv + 166 pp., price unknown.

Roy, Ewell P., Floyd L. Corty, and Gene D. Sullivan. *ECONOMICS: Applications to Agriculture and Agribusiness.* Illinois: Interstate Printers & Publishers, 1975, 569 pp., price unknown.

Seidman, Ann. *Natural Resources and National Welfare: The Case of Copper.* New York: Praeger Publishers, 1975, xvii + 453 pp., price unknown.

Sjo, John. *Economics For Agriculturalists: A Beginning Text in Agricultural Economics.* Grid, Inc., xii + 232 pp., price unknown.

Smole, William J. *The Yanoama Indians.* London: University of Texas Press, 1976, xiv + 272 pp., $10.95.

Sorenson, Vernon L. *International Trade Policy: Agriculture and Development.* Michigan: Division of Research, Graduate School of Business Administration, Michigan State University, 1975, xix + 290 pp., $11.00, $6.00 paper.

Spitzer, Hartwig. *Regionale Land Wirtschaft.* Hamburg: Verlag Paul Parey, 1975, 203 pp., price unknown.

Sposito, V. A. *Linear and Nonlinear Programming.* Ames: Iowa State Press, 1975, x + 269 pp., $12.95.

Stuhler, Elmar A., and Henry B. Arthur. *Studies Dealing with Agricultural Business Following the Harvard-Case-Method.* Hamburg: Verlag Paul Parey, 1975, 348 pp., price unknown.

Announcements

Annual Meeting, 1976

The annual meeting of the American Agricultural Economics Association will be held 15–18 August at Pennsylvania State University in University Park, Pennsylvania. Professor James Holt is chairman of the local arrangements committee. The Northeastern Agricultural Economics Council will be meeting jointly with the AAEA.

1976 Meeting Allied Social Sciences Association

The American Agricultural Economics Association will meet jointly with the Allied Social Sciences Association in Atlantic City, New Jersey, 16–18 September 1976. Tentatively, sessions are being scheduled as follows: (*a*) contemporary economic issues (round table discussion), (*b*) financing local government services, (*c*) fiscal policy issues, and (*d*) economics of the household. Program details are available from Kenneth R. Farrell, President-Elect, AAEA, Economic Research Service, U.S. Department of Agriculture, Washington, D.C. 20250.

Change in Farm Foundation Program

Effective 1 May 1976, the Farm Foundation will provide financial and staff support for research activities on an ad hoc basis, rather than through ongoing regional research committees. This change applies only to research, not extension. The purpose of the program change is to strengthen the catalytic role of the Farm Foundation in social science research. No change is proposed in the Foundation's policy of working with the land grant colleges, the U.S. Department of Agriculture, and related organizations. The new program is not a grants program. The Foundation staff will continue to help develop and participate in the activities it supports. As in the past, researchers and other individuals will be brought together to specify research problems and needs, to develop research strategies, or to seek improvements in data and research methodology.

Activities may be instigated by the Foundation staff or by requesting organizations and individuals. Requests for support may come from any of the following: researchers, experiment station directors and deans, department heads, research groups or planning committees in the land grant-U.S. Department of Agriculture system, government agencies, extension personnel, and other users of research.

The Foundation intends to maintain its informal style. Rather than require overly formal proposals, the request should state the purpose, the procedure, intended results, duration, and the nature of support desired. As in the past, expenses of the activities supported will be paid directly by the Farm Foundation. Requests may be made for support of a single activity, such as one meeting, or for a "package" (sequence of activities), with a maximum of two years' support. The activity may be multistate, regional, or national. It may focus on a commodity issue, a research methods issue, or a policy issue.

Three main criteria will be used: the importance of the problem, professional and institutional improvement, and the likely payoff. Highest priority will be given to activities concerned with agricultural and rural problems that the Foundation views as significant to the future well-being of rural people. Applied research, the development of more basic knowledge, new theoretical approaches, and methodological or data improvements will be given equal attention. Activities to strengthen the capability of professionals and their institutions to produce useful research knowledge will be supported, provided that they are treated as "means" rather than as "ends." Activities involving researchers from smaller land grant colleges will be considered carefully in this context. Included in the payoff criterion are questions such as the following. Is the activity likely to produce significant results in the near future? Is the "spin off" potential high? Does the activity reflect new thinking? Use of these criteria will depend largely on the judgment of the Foundation staff, not on formal grading or weighting techniques. Further guidelines may be forthcoming as program experience is gained.

The initiators of each activity will be expected to provide a short report on the activity written in such a way that it will indicate to other researchers and administrators, as well as certain users of research, new insights emerging from the activity. The Foundation will not automatically support the publication of proceedings of activities such as conferences and seminars. Separate requests for such support will be required.

Requests for support should be made to R. J. Hildreth, Managing Director, or W. Neill Schaller, Associate Managing Director, at the following (new) address: Farm Foundation, 1211 West 22nd Street, Oak Brook, Illinois 60521.

AAEA Committee Structure, 1975–76

AAEA Representative to the Agricultural Development Council Research and Training Network Program

C. Peter Timmer, Cornell University

AAEA Representative to the Bureau of Census Advisory Committee on Agricultural Statistics

M. L. Upchurch, University of Florida

AAEA Representative to Federal Statistics Users Conference

Norman M. Coats, Ralston Purina Co.

AAEA Representative to the National Bureau of Economic Research

Harold G. Halcrow, University of Illinois

AAEA Representative to the National Research Council

John C. Redman, University of Kentucky

Alternative Publications

Verner G. Hurt, Chairman, Mississippi State University, 1975
Harold F. Breimyer, University of Missouri, 1975
Ben C. French, University of California, Davis, 1975
Glenn E. Heitz, Federal Land Bank of St. Louis, 1975
Paul E. Nelson, Economic Research Service, USDA, 1975
Stephen C. Smith, University of Wisconsin, 1975
Glen V. Vollmar, University of Nebraska, 1975

American Statistical Association, AAEA Joint Advisory Committee on Agricultural Statistics

R. James Hildreth, Chairman, Farm Foundation
Dean E. McKee, John Deere and Co.
Luther G. Tweeten, Oklahoma State University

Audit

James E. Criswell, Chairman, University of Kentucky, 1970
Larry D. Jones, University of Kentucky, 1974

Awards

Paul L. Kelley, General Chairman, Kansas State University, 1974

Distinguished Extension Programs

Everett Peterson, Chairman, University of Nebraska, 1974
Robert J. Bevins, University of Missouri, 1975
H. Doss Brodnax, Mississippi State University, 1974
Charles W. Coale, Virginia Polytechnic Institute and State University, 1975
George A. Ecker, University of Connecticut, 1974
John Holt, University of Florida, 1973
Verne W. House, Montana State University, 1974
Ray Prigge, University of Idaho, 1975

Distinguished Undergraduate Teaching

R. G. F. Spitze, Chairman, University of Illinois, 1973
Hoy F. Carman, University of California, Davis, 1973
Maurice J. Danner, Auburn University, 1975
Billy V. Lessley, University of Maryland, 1974
James E. Osborn, Texas Tech University, 1975
Richard W. Schermerhorn, University of Idaho, 1974
Kenneth C. Schneeberger, University of Missouri, 1975

Outstanding Doctoral Program

Forrest E. Walters, Chairman, Colorado State University, 1973
Harry W. Ayer, University of Arizona, 1975
David M. Bell, Economic Research Service, USDA, 1973
Dale C. Dahl, University of Minnesota, 1975
Terry Glover, Utah State University, 1975
Charles R. Handy, Economic Research Service, USDA, 1973
Douglas D. Hedley, Agriculture Canada, 1973
Ed F. Jansen, University of New Hampshire, 1975
Abbas Mirakhor, University of Alabama, Huntsville, 1974

Earl J. Partenheimer, Pennsylvania State University, 1973
Gordon C. Rausser, Iowa State University, 1974
C. Richard Shumway, Texas A&M University, 1974
L. Orlo Sorenson, Kansas State University, 1973

Outstanding Master's Program

Joseph Havlicek, Jr., Chairman, Virginia Polytechnic Institute and State University, 1973
Thomas A. Carlin, Economic Research Service, USDA, 1975
Thomas Daves, South Dakota State University, 1975
Olan D. Forker, Cornell University, 1975
William D. Gorman, New Mexico State University, 1974
Jerry M. Law, Louisiana State University, 1973
Dale J. Menkhaus, University of Wyoming, 1974
Glenn Nelson, Purdue University, 1975
J. B. Penn, Economic Research Service, USDA, Raleigh, North Carolina, 1974
Travis D. Phillips, Mississippi State University, 1974
Travis D. Phillips, Missippi State University, 1974
Robert Raunikar, University of Georgia, Experiment, 1973
Robert N. Shulstad, University of Arkansas, 1974
Heinz Spielmann, University of Hawaii and Economic Research Service, USDA, 1974

Publications, Quality of Communication

A. Gordon Ball, Chairman, University of Guelph, 1975
W. G. Aanderud, South Dakota State University, 1975
Jack H. Armstrong, Farmer Cooperative Service, USDA, 1973
Roger W. Fox, University of Arizona, 1973
Dennis R. Henderson, Ohio State University, 1973
Sidney Ishee, University of Maryland, 1975
Wayne D. Rasmussen, Economic Research Service, USDA, 1973
Mary E. Templeton, West Virginia University, 1973

Publications, Quality of Research Discovery

A. Gordon Ball, Chairman, University of Guelph, 1974
Bruce W. Cone, Battelle Pacific Northwest Laboratory, 1974
William D. Dobson, University of Wisconsin, 1973
Irving Dubov, University of Tennessee, 1975
Clark Edwards, Economic Research Service, USDA, 1975
Burton L. French, Economic Research Service, USDA, 1973
Stanley R. Johnson, University of Missouri, 1973
Andrew Vanvig, University of Wyoming, 1973
Cleve E. Willis, University of Massachusetts, 1975

Publications of Enduring Quality

Vernon R. Eidman, Chairman, University of Minnesota, 1973
Thomas F. Hady, Economic Research Service, USDA, 1973
A. H. Harrington, Washington State University, 1975
Neil R. Martin, University of Georgia, 1975
Allen B. Paul, Economic Research Service, USDA, 1973
Alan Randall, University of Kentucky, 1974
Ronald A. Schrimper, North Carolina State University, 1973
Stephen H. Sosnick, University of California, Davis, 1975
Kenneth E. Wing, University of Maine, 1975

Nomination of Agricultural Economist for the Edward W. Browning Award of the American Society of Agronomy

Lowell S. Hardin, Chairman, Ford Foundation, 1973
Willard W. Cochrane, University of Minnesota, 1973
Gordon A. King, University of California, Davis, 1973
Nathan M. Koffsky, International Bank for Reconstruction and Development, 1973

Bibliographical-Retrospective Search

J. Edwin Faris, Chairman, Clemson University, 1970
Allan S. Johnson, Economic Research Service, USDA, 1973
Marvin G. Julius, Iowa State University, 1974
Richard C. McArdle, Economic Research Service, 1973
Ivan W. Schmedemann, Texas A&M University, 1970
John T. Scott, University of Illinois, 1972
R. C. Smith, University of Delaware, 1974

Contributed Papers, 1976 Annual Meeting

Quentin M. West and Eldon E. Weeks, Cochairmen, Economic Research Service, USDA

Economic Statistics

R. James Hildreth, Chairman, Farm Foundation, 1969
W. Keith Bryant, Cornell University, 1974

Norman M. Coats, Ralston Purina Co., 1975
Harry C. Trelogan, Statistical Reporting Service, USDA, 1970
Luther G. Tweeten, Oklahoma State University, 1974
Quentin M. West, Economic Research Service, USDA, 1972
Gaylord E. Worden, Economic Research Service, USDA, 1974

Employment Services

Loys L. Mather, Chairman, University of Kentucky, 1968
Joseph Ackerman, National Employment Registry for Agricultural Economists, 1973
Raymond R. Beneke, Iowa State University, 1974
Carleton C. Dennis, Agway, 1972
G. T. Dowdy, Tuskegee Institute, 1974
Stephen B. Harsh, Michigan State University, 1973
Dale E. Hathaway, International Food Policy Research Institute, 1971
Melvin R. Janssen, Economic Research Service, USDA, 1969

Evaluation of Annual Meeting Program

Henry J. Meenen, Chairman, University of Arkansas, 1975
Charles L. Beer, Federal Extension Service, USDA, 1975
Joseph D. Coffey, Virginia Polytechnic Institute and State University, 1975
Otto J. Doering, Purdue University, 1975
Richard T. Herder, Central Soya, 1975
John G. McNeely, Texas A&M University, 1975
Kenneth C. Nobe, Colorado State University, 1975
Lawrence W. Witt, U.S. Department of State, 1975

Extension Affairs

Robert L. Christensen, Chairman, University of Massachusetts, 1975
Charles D. Covey, University of Florida, 1973
Norbert Dorow, North Dakota State University, 1975
W. S. Farris, Purdue University, 1975
Robert C. Matthes, Kentucky Fried Chicken, 1974
Gene Nelson, Oregon State University, 1975
Bobby H. Robinson, Clemson University, 1975
Charles H. Rust, Montana State University, 1974

Fellows Election

Karl A. Fox, Chairman, Iowa State University, 1972
Marion Clawson, Resources for the Future, 1975
Vernon W. Ruttan, Agricultural Development Council, 1974
Lauren K. Soth, Des Moines Register and Tribune, 1973
Holbrook Working, Stanford University, 1975

Finance

B. F. Stanton, Chairman, Cornell University, 1974
Wallace Barr, Ohio State University, 1975
Peter J. Barry, Texas A&M State University, 1975
Michael D. Boehlje, Iowa State University, 1975
John C. Redman, University of Kentucky, 1974

Handbook-Directory

Howard F. Robinson, Chairman, North Carolina A&T State University, 1974
Joseph Ackerman, National Employment Registry for Agricultural Economists, 1974
Emanuel O. Melichar, Federal Research System, 1974
John C. Redman, University of Kentucky, 1974

Industry Advisory Committee

Eugene E. Gerke, Chairman, Supermarket Institute, 1974
Paul A. Baumgart, Safeway Stores, 1974
Charles E. Erickson, Cargill, 1974
W. Bernard Lester, Florida Citrus Commission, 1973
Walter M. Myers, Connell Rice and Sugar Co., 1975
Ted Rice, Continental Grain Co., 1973
Bruce A. Scherr, Data Resources, 1975
Ed Williams, Massey-Ferguson, 1975
Arthur G. Wilson, Canada Grains Council, 1974

International

Orlin J. Scoville, Chairman, Winrock International Livestock Center, 1972
J. Price Gittinger, International Bank for Reconstruction and Development, 1973
James P. Houck, Jr., University of Minnesota, 1973
William C. Merrill, Agency for International Development, 1975
Harold M. Riley, Michigan State University, 1975
Wayne W. Sharp, President's Council on Economic Policy, 1973
C. Peter Timmer, Cornell University, 1974
Abraham M. Weisblat, Agricultural Development Council, 1973

Local Arrangements

AAEA Representative to Allied Social Science Associations Winter Meetings, 1975

Carl G. Anderson, Jr., Federal Reserve Bank of Dallas

Annual Meeting, 1976

James S. Holt, Chairman, Pennsylvania State University

Membership

John E. Lee, Chairman, Economic Research Service, USDA, 1972
David Y. Chen, North Carolina A&T State University, 1974
Norman R. Collins, Ford Foundation, 1975
John E. Cottingham, Wisconsin State University, 1975
Thomas L. Frey, University of Illinois, 1975
John D. Graham, University of British Columbia, 1975
James L. Pearson, University of Florida, 1975
Donald G. Stitts, University of Connecticut, 1975
Norman K. Whittlesley, Washington State University, 1975
Ed Williams, Massey-Ferguson, 1974

National Professional Employment Registries

David H. Boyne, Chairman, Ohio State University, 1975
Raymond R. Beneke, Iowa State University, 1975
Orville Bentley, University of Illinois, 1975
Richard J. McConnen, Montana State University, 1975
James S. Plaxico, Oklahoma State University, 1975
Leo Polopolous, University of Florida, 1975

Nominating

James Nielson, Washington State University, 1975
Glenn C. Himes, Ohio State University, 1975
Richard J. McConnen, Montana State University, 1975
William C. Motes, Economic Research Service, USDA, 1975
Ted Rice, Continental Grain Co., 1975
Fred H. Tyner, Mississippi State University, 1975
T. K. Warley, University of Guelph, 1975

Postwar Literature Review

Lee R. Martin, Chairman, University of Minnesota, 1967
John P. Doll, University of Missouri, 1968
Peter G. Helmberger, University of Wisconsin, 1969
Glenn L. Johnson, Michigan State University, 1967
Maurice M. Kelso, University of Arizona, 1967
J. Patrick Madden, Pennsylvania State University, 1969
Edward W. Tyrchniewicz, University of Manitoba, 1969
M. L. Upchurch, University of Florida, 1967

Professional Activities

Paul W. Barkley, Chairman, Washington State University, 1975
Donald R. Levi, Texas A&M University, 1975
Larry W. Libby, Michigan State University, 1975
Kenneth D. McIntosh, West Virginia University, 1975
J. Paxton Marshall, Virginia Polytechnic Institute and State University, 1975
Philip M. Raup, University of Minnesota, 1975
Bernard L. Sanders, Farmland Industries, 1975
Gene L. Wunderlich, Economic Research Service, USDA, 1975

Publication of Postwar Literature Review

Emerson M. Babb, Chairman, Purdue University, 1974
J. Patrick Madden, Pennsylvania State University, 1974
John C. Redman, University of Kentucky, 1974

Resident Instruction Committee

Glenn C. Himes, Chairman, Ohio State University, 1974
Larry Johnson, University of Georgia, 1975
Lonnie L. Jones, Texas A&M University, 1973
James G. Kendrick, University of Nebraska, 1973
A. Robert Koch, Rutgers University, 1975
Hong Lee, Texas Tech University, 1975
Milton M. Snodgrass, New Mexico State University, 1975
Walter J. Wills, Southern Illinois University, 1974

Review of AAEA Constitution and Bylaws

Neil E. Harl, Chairman, Iowa State University, 1975
John E. Kadlec, Purdue University, 1975
John C. Redman, University of Kentucky, 1975

Review of Fellows Selection Process

Harry C. Trelogan, Chairman, Statistical Reporting Service, USDA, 1975

Joseph Ackerman, National Employment Registry for Agricultural Economics, 1975
George Brandow, Pennsylvania State University, 1975
Emery N. Castle, Resources for the Future, 1975
John O. Dunbar, Purdue University, 1975
William D. Toussaint, North Carolina State University, 1975

Tellers

A. Frank Bordeaux, Jr., Chairman, University of Kentucky, 1973
Harry H. Hall, University of Kentucky, 1973

U.S. Council of the International Association of Agricultural Economists, 1973–76

M. L. Upchurch, Chairman, University of Florida
Norman R. Collins, Ford Foundation
Max Myers, South Dakota State University
Lyle P. Schertz, Economic Research Service, USDA

Visiting Lecturer

William Herr, Southern Illinois University, 1973
Willard W. Cochrane, University of Minnesota, 1975
R. Vern Elefson, Wisconsin State University, 1975
Wayne D. Purcell, Oklahoma State University, 1975
W. Neill Schaller, Farm Foundation, 1975
John Sjo, Kansas State University, 1975
T. T. Williams, Southern University and A&M College, 1973

Personnel

Agricultural Development Council

Appointments: William L. Collier, former council associate at Bogor, Indonesia, is in the Department of Agricultural and Resource Economics, University of Hawaii, Honolulu, for one year; **Max R. Langham,** formerly at University of Florida, is a research officer for the Regional Research and Training Program, Singapore.

University of Arizona

Appointments: John L. Fischer, professor of agricultural economics, is the coordinator, Africa Programs, Consortium for International Development; **James C. Wade,** formerly at Iowa State University, is an assistant professor of agricultural economics and assistant agricultural economist.
Return: William E. Martin, professor of agricultural economics, is back from a sabbatical spent at the Food Institute, East-West Center, Honolulu, Hawaii.

University of California, Berkeley

Appointment: Sidney Hoos, former university dean of academic personnel in the University of California System (statewide), is a professor of agricultural and resource economics, economics, and business administration.
Honor: Sidney Hoos has been elected a member of the Canners League of California Hall of Fame.

University of California, Davis

Appointments: Ben C. French, professor, is the chairperson of the Department of Agricultural Economics, effective July 1976.
Leave: Warren E. Johnston, professor, is spending his sabbatical in the Department of Farm Management, Lincoln College, Christchurch, New Zealand, July 1976–June 1977.

Cornell University

Appointments: Olan D. Forker, professor of marketing, is the chairman of the Department of Agricultural Economics, effective April 1976; **Wayne Knoblauch,** Ph. D. Michigan State University, is an assistant professor of farm management and production economics, effective May 1976.
Leaves: John W. Mellor, professor of agricultural economics, is the chief economist for the Agency for International Development, Washington, 1976–77; **Bernard F. Stanton** is a visiting fellow in the Development Studies Center, Australian National University, Canberra, May–August.
Retirement: Edward A. Lutz, professor of public administration, effective June 1976.

University of Florida

Appointments: Peter Jon Van Blokland, formerly at the University of Illinois, and **Robert L. Degner,** formerly at Texas A&M University, are assistant professors; **W. Gordon Kearl,** on leave from the University of Wyoming, is a visiting professor, January–July; **Karl Kepner,** formerly at Purdue University, and **J. Robert Strain,** formerly at Iowa State University, are professors; **Burl F. Long,** on leave from the Virginia Polytechnic Institute and State University, is a visiting professor, March–September; **Reza Soltani,** on leave from Pahlavi University, Shirza Iran, is a U.S. Agency for International Development postdoctoral trainee, 1976; **Ronald Ward,** formerly in the Florida Department of Citrus, is an associate professor.
Reassignments: Bernard W. Lester is a deputy director, Department of Citrus, Lakeland; **Daniel S. Tilley** is an assistant professor in the Florida Department of Citrus.
Retirement: G. Norman Rose has left after 32 years of service.

University of Georgia

Appointment: William Anderson Thomas, Ph. D. Clemson University, is an extension marketing economist.

University of Guelph

Appointments: Fred Buzzelli, chartered accountant, is a lecturer in agricultural business; **Janos Hrabovsky,** on leave from the Food and Agriculture Organization, is a visiting professor in economic development, April–August; **Steve Thompson,** M.B.A. University of Western Ontario, has been appointed lecturer in farm and financial management.

Iowa State University

Appointments: James D. Libbin is a research associate; **James M. McGrann,** former assistant pro-

ASCS: Agricultural Stabilization and Conservation Service; CED: Commodity Economics Division; EDD: Economic Development Division: FDD: Foreign Development Division of ERS; NEAD: National Economic Analysis Division of ERS; NRED: National Resource Economics Division of ERS; SCS: Soil Conservation Service.

fessor at Texas A&M University, is an assistant professor.
Resignation: John A. Otte, former research associate.

University of Kentucky

Appointment: David Heisterberg, M.S. University of Missouri, is a farm management specialist, Extension Division.

University of Maryland

Appointment: Billy V. Lessley is acting chairman of the Department of Agricultural and Resource Economics.

University of Minnesota

Appointments: Wallace C. Hardie, M.S. North Dakota State University, is a research specialist in dairy economics; **Ian C. Wills,** Ph.D. University of Illinois and a member of the Faculty of Economics and Politics at Monash University, Clayton, Victoria, Australia, is a visiting associate professor, January–June.
Leave: James P. Houck, professor, is at North Carolina State Agricultural and Technical State University, winter 1976.

University of Missouri

Appointment: Loyd K. Fischer, on leave from the University of Nebraska, is a visiting professor of natural resource economics.
Honors: Thomas G. Brown received a National Council Certificate of Recognition from Epsilon Sigma Phi; **Carl Utterstrom,** M.S. University of Missouri, received first place in the American Institute of Cooperation's M.S. thesis competition.

University of Nebraska

Appointment: J. David Aiken, J. D. George Washington University, formerly with NRED ERS, is a water specialist in the Department of Agricultural Economics.

University of Nevada

Appointments: Edmund R. Barmettler, professor, is an assistant to the dean of the College of Agriculture; **Chauncey T. K. Ching,** associate professor, is the chairman of the Division of Agricultural and Resource Economics; **Ronald Shane,** Ph.D. North Carolina State University, is an assistant professor of agricultural and resource economics.

New Mexico State University

Appointment: Michael Cook, Ph.D. University of Wisconsin, is working in the area of agricultural marketing.

Oklahoma State University

Appointments: James E. Casey, Jr., formerly at Texas A&M University, **Loren L. Parks,** formerly at the University of California, Davis, and **Joseph E. Williams,** formerly at Iowa State University, are assistant professors in production economics.

Oregon State University

Appointment: Roger G. Kraynick, Ph.D. University of Colorado, is a research associate.
Honor: Frank S. Conklin, associate professor, received the R. M. Wade Award for Outstanding Teacher in the School of Agriculture for 1975.

Pennsylvania State University

Appointment: C. Edwin Young, Ph.D. North Carolina State University, is an adjunct assistant professor of resource economics.
Retirement: C. William Pierce is a professor emeritus of agricultural economics after 29 years of service.
Honor: Clare A. Becker, professor of agricultural economics, received the Distinguished Service Award from the Pennsylvania Association of Farmer Cooperatives.

Purdue University

Appointments: Oscar Goldman is a temporary assistant professor of agricultural economics and an investigator on a National Science Foundation project entitled "Evaluating Milk Order Alternatives"; **Donald A. Hilger** is a grain market analyst; **William H. King** is a community development analyst; **Patrick D. O'Rourke** is a program development coordinator; **Gary Van Hoozer** is a temporary instructor and a grain market analyst; **James K. Whittaker** is an assistant professor of agricultural economics and is researching and teaching in production economics and farm management.

Rutgers University

Retirement: George W. Luke, professor of agricultural economics and marketing, department chair-

man (1957–70), and member of the Governor's Farmland Assessment Committee.

South Dakota State University

Appointments: Ardelle Lundeen, Ph.D. Iowa State University, and **Patrick A. Lyons** are assistant professors.
Leave: John E. Thompson, head of the Economics Department, is spending his six-month sabbatical in Washington, England, and Scandinavian countries.

Texas A&M University

Appointments: Gary D. Condra, former research associate at the Water Resources Institute, is an area extension economist-management at Ft. Stockton; **Milten E. Rister,** former research assistant, is an instructor in farm management; **Charles R. Taylor,** former assistant professor of agricultural economics and agricultural entomology at the University of Illinois, is an assistant professor; **Richard Trimble,** former assistant professor of agriculture and extension economics at the University of Guelph, Canada, is an extension specialist-management.

U.S. Department of Agriculture

Appointments: Robert Pfeiffer, Ph.D. University of Missouri, is a research economist with ERS at Little Rock, Arkansas; **John T. Steele,** former associate professor at Texas A&M University, is with the International Training Division.
Appointments in NEAD: Marilyn Altobello, Ph.D. University of Massachusetts, and **Timothy Baker,** formerly at Michigan State University, are with the Inputs and Finance Program Area; **Gene K. Lee,** formerly at Washington State University, and **Joseph Roop,** formerly with the Office of the Director at Large, Western Association of Agricultural Experiment Station Directors at Berkeley, California, are with the Aggregate Outlook Program Area; **Robert R. Miller,** formerly with CED's Dairy Group, is the economics editor of the ERS monthly *Agricultural Outlook*; **Thomas Stafford,** formerly with the United Dairy Industry Association at Rosemont, Illinois, is with the Distribution Analysis Research Program Area.
Appointments in NRED: Larry Boone, formerly at Lincoln, Nebraska, is on a two-year assignment with the Agency for International Development in Costa Rica; **Norman D. Kimball,** formerly at Berkeley, California, is on a one-year assignment with the Food and Agriculture Organization, Tanzania; **Reuben N. Weisz,** former assistant professor at the University of Arizona.
Reassignments: Walter J. Armbruster, formerly with NEAD ERS, is a staff economist with the Agricultural Marketing Service; **John L. Okay,** formerly with SCS, is a program analyst with the Cooperative State Research Service; **Charles Palmer,** formerly with the Southwest Resource Program Group at Denver, is with the U.S. Forest Service at Denver; **W. Fred Woods,** formerly with NEAD ERS, is a public policy specialist with the Extension Service.
Reassignments in CED: Luigi Angelo and Ludwin Speir, formerly with ASCS, are with the Fruits, Vegetable, Sweetener, and Tobacco Program Area; **Robert W. Bohall,** formerly with the Fruits, Vegetable, Sweetener, and Tobacco Program Area, is the acting deputy director; **Edward V. Jesse,** formerly at Davis, California, is the temporary program leader of the Fruits, Vegetable, Sweetener, and Tobacco Program Area.
Reassignments in EDD: Tom Carlin, formerly with NEAD, is the leader of the Income Studies Program; **Robert Coltrane** is the leader and **Conrad Fritsch** is the project leader of the Manpower Studies Program Area.
Reassignments in NRED: Joseph R. Barse, formerly with FDCD, is working on a special project related to environmental studies; **Daniel J. Dudek** is with the Southwest Resource Program Group at Davis, California; **Paul Dyke,** formerly at Corvallis, Oregon, is with the Resource Projections and Analytical Systems Group; **Joe Green,** formerly at Upper Darby, Pennsylvania, is studying the economic impacts of coal and shale oil development at Fort Collins, Colorado; **Roger W. Hexem,** formerly in Washington, is with the Northeast Resource Program Group at Cornell University; **Robert McKusick,** formerly at Davis, California, is the leader of the Small Watershed and Resource Conservation and Development Program Area; **Arnold Miller,** formerly at East Lansing, Michigan, is with the Office of Management and Finance.
Resignations in CED: Hilarius W. Fuchs is with Continental Grain, New York State; **Wyatte L. Harman** is with Con-Agra, Nebraska.
Honor in CED: Preston E. LaFerney was accepted for fellowships in Congressional Operations through August 1976.

Washington State University

Appointment: Jagjit Brar, former assistant professor at Southeastern Louisiana State University, is an assistant professor.

University of Wisconsin

Appointment: Richard Schoney, Ph.D. Purdue University, is working in farm management extension.
Leave: Truman F. Graf is on leave to work in

Bucharest on agricultural marketing in Romania, March–June.

Return: Duncan A. Harkin is back after a two-year stay in the Philippines working on a cooperative project with the Agrarian Reform Institute, the University of the Philippines-Los Banos and the Land Tenure Center, University of Wisconsin.

Other Appointments

Robert A. Bain, Ph.D. Cornell University, is the officer in charge of the Livestock Commodities Section, Bureau of Agricultural Economics, Canberra, Australia.

Juan A. B. Belt, former research associate at Cornell University, is a staff economist at the Instituto Centro-Americano de Administracion de Empresas, Managua, Nicaragua.

John Bobbe, M.S. University of Missouri, is the director of marketing division of the National Farmers Organization, Corning, Iowa.

Peter H. Calkins, former research assistant at Cornell University, is head of the Department of Agricultural Economics, International Vegetable Research and Development Center, Taiwan.

William Lee Davis, M.S. University of Missouri, is an economist with the CIA.

Lloyd Allen Dever, Jr., M.S. University of Missouri, is a commodity analyst at Doane Agriculture, St. Louis.

James C. Fink, Jr., is with Chilton Research Services, Radnor, Pennsylvania.

Robert F. Glenn, Ph.D. University of Missouri, is an assistant professor at Southwest Missouri State University.

Albert N. Halter, former professor at Oregon State University, is at the Electric Power Research Institute, Palo Alto, California.

Van Harrold, M.S. University of Missouri, is a fieldman with Saganon Valley Farm Management Association, Lincoln, Illinois.

John Helmuth, formerly with the NEAD ERS, is a staff economist with the Commodity Futures Trading Commission.

James Hendren, M.S. University of Missouri, is with the Federal Land Bank, St. Louis.

James Lewellen, M.S. University of Missouri, is a trainee with the Federal Intermediate Credit Bank, St. Louis.

Russell F. McDonald, former state extension economist-marketing at Texas A&M University, is with the Commodity Futures Trading Commission, Washington.

James Stricker, M.S. University of Missouri, is the superintendent of the University of Missouri Forage Systems Research Center, Linneus.

Mohamad Yusoff Yahaya, M.S. University of Missouri, is a marketing economist with the Farmers Organization Authority, Kuala Lumpur, Malaysia.

Ph.D. Recipients by Subject

Agricultural Finance, Capital, Credit

Leslie Gene Carlow, B.S. University of Nebraska, 1968; M.S. University of Nebraska, 1972; Ph.D. University of Nebraska, "Capital in Nebraska Agriculture: Its Formation, Distribution, and Financing."

Richard J. Edwards, B.S. Cornell University, 1961; M.S. Purdue University, 1966; Ph.D. Purdue University, 1974, "The Cost of Assessing Property in Indiana, Iowa and Wisconsin: 1963."

Alan Kent Reichert, B.S. Miami University, 1968; M.S. Ohio State University, 1973; Ph.D. The Ohio State University, "The Effect of Bank Holding Company Growth in Ohio's Rural Capital Markets."

Agricultural Labor; Rural Manpower

Evonir Batista de Oliveira, B.S. Faculdade de Econ e Financa, 1962; M.S. Univ. Rural Minas Gerais, 1966; Ph.D. Purdue University, 1974, "Agricultural Employment and Land Reform in Brazil."

Sue Eileen Hayes, B.A. Stanford University, 1965; M.S. University of California, Berkeley, 1973; Ph.D. University of California, Berkeley, "Seasonal Workers in Extended Employment: Implications for Agricultural Labor Policy."

Roger Neil Sexton, B.Ec. Flinders University of South Australia, 1971; M.E. North Carolina State University, 1974; Ph.D. North Carolina State University, "Determinants of Multiple Job-Holding by Farm Operators."

Neil John Steeper, B.Ag.Ec. University of New England—Australia, 1964; M.Ag.Ec. University of New England—Australia, 1974; Ph.D. North Carolina State University. "A Portfolio Approach to Occupational Adjustment Applied to U.S. Farmers' Families, 1945 to 1970."

Agricultural Products: Demand, Supply, Prices

William T. Boehm, B.S. Wisconsin State University, 1970; M.S. Purdue University, 1972; Ph.D. Purdue University, 1974. "An Econometric Analysis of the Household Demand for Major Dairy Products."

Roe Everett Borsdorf, B.S. Kansas State University, 1957; M.S. Kansas State University, 1971; Ph.D. Kansas State University, "An Investigation into Forecasting Planted Crop Acreages in the Short Run as a Quantitative Measurement Tool for Agribusiness Management."

Wen Shyong Chern, B.S. Provincial Chung-Hsing University, 1964; M.S. University of Florida, 1969; M.S. University of California, Berkeley, 1971; Ph.D. University of California, Berkeley, "Supply Response and Price-Demand Relationships for California Processing Tomatoes."

Oscar Goldman, M.S. National University of Rosario, 1972; Ph.D. The Pennsylvania State University, "A Quarterly Econometric Model of the U.S. Dairy Subsector—1955–72."

Ralph G. Lattimore, B.S. Lincoln College, 1968; M.S. Massey University, 1971; Ph.D. Purdue University, 1974, "An Econometric Study of the Brazilian Beef Sector."

Chun-Lan Lee Liu, B.S. National Taiwan University, 1965; M.S. Southern Illinois University, 1970; Ph.D. University of Illinois, "Optimal, Temporal, and Spatial Pricing and Allocation of Wheat in the International Market."

Adolfo Martinez, B.S. Universidad Nacional de Colombia, Facultad de Agronomia, Palmira, 1970; M.S. Louisiana State University, 1973; Ph.D. Louisiana State University, "An Economic Analysis of Effects of Selected Quality and Non-Quality Factors on Prices of Medium and Long Grain Rough Rice in Louisiana."

Robert Alexander Milligan, B.S. Michigan State University, 1969; M.S. Michigan State University, 1971; Ph.D. University of California, Davis, "An Econometric Model of the California Dairy Industry."

Stanley Robert Thompson, B.S. California State Polytechnic University, 1968; M.S. Oregon State University, 1970; Ph.D. Cornell University, "An Econometric Analysis of Sales Response to Generic Fluid Milk Advertising in New York State."

Trevor Young, B.A. University of Nottingham, 1970; M.S. Victoria University of Manchester, 1972; Ph.D. University of California, Berkeley, "Grouping of Commodities in Demand Analysis."

Cooperatives and Cooperation

Wilmer A. Dahl, B.S. University of Wisconsin-Whitewater; M.S. University of Wisconsin-Madison; Ph. D. University of Wisconsin-Madison, "Alternative Financial Management Strategies for Local Farm Supply Cooperatives in Wisconsin."

Donald R. Schwartz, B.A. South Dakota State University, 1969; M.S. South Dakota State University, 1971; Ph.D. Purdue University, 1974, "Vertical Coordination in Cooperative Grain Marketing Systems."

The names of Ph.D. recipients are provided by departments of agricultural economics and by departments of economics with majors in agricultural economics. The list is for degrees granted in the calendar year 1975, unless otherwise noted.

Economic Development, Growth, and Planning

Suleiman Mufleh Arabiyat, B.S. Damascus University, 1965; M.S. University of Arizona, 1969; Ph.D. Mississippi State University, "Interindustry Analysis as an Aid in Planning for Economic Development in Underdeveloped Areas: Application to the Jordanian Economy."

Amir Baharuddin, B.S. Louisiana State University, 1970; M.S. Louisiana State University, 1971; Ph.D. University of Missouri, "An Economic Analysis of the Agricultural Development Potential for Southern Honduras."

Khairulah Dawalty, B.S. Kabul University, 1962; M.S. University of Wyoming, 1965; Ph.D. University of Tennessee, "A Two-Stage Estimate of Underemployment of the Male and Female Labor Force, by County, Tennessee, 1960 and 1970."

Bhupendra Maganlal Desai, B.A. University of Bombay, 1961; M.A. Sardar Patel University, India, 1963; Ph.D. Cornell University, "Relationship of Consumption and Production in Changing Agriculture: A Study in Surat District, India."

Arthur Lee Roy Ekholm, Jr., B.A. University of Texas, 1962; M.A. Texas Christian University, 1968; Ph.D. Oklahoma State University, "Regional Economic Adjustment to the Depletion of Groundwater and Petroleum: High Plains of Oklahoma and Texas."

Mohamed H. El-Hurani, B.S. Cairo University, 1969; M.S. Portland State University, 1972; Ph.D. Iowa State University, "Economic Analysis of the Variation and Development of the Wheat Subsector of Jordan."

Gafsi Salem, M.S. University of Tennessee, 1970; Ph.D. University of Minnesota, "Green Revolution: The Tunisian Experience."

Farrokh Ghobadi, B.A. Sacramento State College, 1969; M.S. Iowa State University, 1973; Ph.D. Iowa State University, "Estimated Impacts of Variation in Wheat Price Policy in Northern Iran.

Dennis Wayne Goins, B.A. Wake Forest University, 1970; M.E. North Carolina State University, 1972; Ph.D. North Carolina State University, "The Demand for Housing in Rural North Carolina."

Leonel Guillermo Gonzalez, B.S. University Rafael Landivar; M.S. University Rafael Landivar; Ph.D. University of Wisconsin-Madison, "Economic Development Potentials in the Production of Vegetables in Guatemala."

Robert A. Gray, B.S. Texas Technological College, 1951; M.Ed. Texas Technological College, 1956; Ph.D. Michigan State University, "Agricultural Export Potentials and Balance of Payments Aspects of the Nigerian Economy."

Kuo-Shiung Huang, B.S. National Taiwan University, 1962; M.S. National Taiwan University, 1965; Ph.D. University of California, Berkeley, "An Econometric Analysis of the Taiwan Economy, 1952–1969."

Morris T. Jones, A.B. Union University, 1966; M.S. University of Tennessee, 1968; Ph.D. University of Tennessee, "Fire Protection Services for Rural Tennessee Communities: A Benefit-Cost Analysis."

Jeung H. Lee, B.S. Seoul National University, 1957; M.S. Seoul National University, 1962; M.S. Iowa State University, 1969; Ph.D. Michigan State University, "Projections of Product Supply and Factor Demand under Structural Change for Korean Agriculture: A Systems Simulation Approach."

Thomas Harold Loftin, B.S. Mississippi State University, 1953; M.S. Mississippi State University, 1966; Ph.D. Mississippi State University, "An Economic Analysis of Rural Water Associations in Mississippi with an Estimated Costs per Customer by System Size."

Diego R. Londono, B.S. Universidad de Caldas, 1962; M.S. Oklahoma State University, 1970; Ph.D. Oklahoma State University, "Economic Analysis of Subsistence Agriculture in Garcia Rovira, Colombia."

Mark A. Lund, B.A. Augsburg College, 1969; Ph.D. Iowa State University, "Identifying, Developing, and Adopting Technologies Appropriate for Rural Development with Applications to Huari Province in Peru."

Ralph D. May, B.S.A. University of Arkansas, 1968; M.S. University of Arkansas, 1972; Ph.D. Purdue University, "A Systems Model of the Cattle Economy—A Guyana Application."

Lu Siong Ng, B.S. Iowa State University, 1969; Ph.D. Iowa State University, "An Income Distribution and Employment Consistency Model of the Philippines."

William C. Nickel, B.A. Rutgers University, 1967; M.S. Rutgers University, 1971; Ph.D. University of California, Berkeley, "Efficiency in Resource Use in Paddy-Intensive Southern Indian Agriculture."

Felix Nweke, B.S. University of Nigeria, 1967; Ph.D. Michigan State University, "A Systems Analysis and Simulation Study of the Nigerian Forestry Sector: Wood Consumption Component."

Soner Ogut, The Diploma of License (B.S.) University of Istanbul, 1965; M.S. University of Illinois, 1972; Ph.D. University of Illinois, "The Effects of Potential Resource Allocation Alternatives on Income and Employment for Three Rural Villages in Central Turkey."

Robert L. Pfeiffer, B.S. Kearney State College, 1956; M.S. University of Missouri, 1972; Ph.D. University of Missouri, "Factors Influencing Labor Force Migration in Missouri, 1960–1970."

Radzuan Bin Abdul Rahman, B.S. University of Malaysia, 1969; M.S. Cornell University, 1972; Ph.D. Cornell University, "The Economics of the Timber Industry in West Malaysia: A Case Study."

Raphael Shen, M.A. Berchmans College, 1965; M.A. Xavier College, 1967; M.A. Michigan State University, 1974, Ph.D. Michigan State University, "Narrowing Taiwan's Per Capita Farm/Nonfarm Income Gap via Increased Agricultural Production and Guaranteed Prices: Projections and Analysis, 1973–1984."

Paul Kelly Steidlmayer, B.A. Gonzaga University, 1965; M.A. Gonzaga University, 1966; Ph.D. Stanford University, "The Da Zhai Model in Chinese Agriculture: A Study of Policy, Its Implementation and Performance (1960–74)."

Fred Joseph Stewart, B.S. University of Montana, 1967; Ph.D. University of Kentucky, "Potential for Increased Net Incomes on Small Farms in Four Eastern Kentucky Counties."

Miguel Teubal, B.S. University of California, Berkeley, 1958; M.A. University of California, Berkeley, 1964; Ph.D. University of California, Berkeley, "Policy and Performance of Agriculture in Economic Development: The Case of Argentina."

Robert L. Thompson, B.S. Cornell University, 1967; M.S. Purdue University, 1969; Ph.D. Purdue University, 1974, "The Metaproduction Function for Brazilian Agriculture: An Analysis of Productivity and Other Aspects of Agricultural Growth."

Eric F. Tollens, B.S. Catholic University of Louvain, 1967; M.A. Michigan State University, 1970; Ph.D. Michigan State University, "An Economic Analysis of Cotton Production, Marketing and Processing in Northern Zaire."

Andres T. Vilas, B.S. Universidade Rural do Estado de Minas Gerais (Vicosa), 1965; M.S. Universidade Federal de Vicosa, U.F.V., 1971; Ph.D. Purdue University, "A Spatial Equilibrium Analysis of the Rice Economy in Brazil."

Jong Tack Yoo, B.A. Seoul National University, 1961; M.S. Montana State University, 1972; Ph.D. Michigan State University, "A Short and Long Run Analysis of the Korean Rural Demand for Food and Its Implications to Agricultural Policies."

Environmental Economics

Jeffrey V. Conopask, B.S. Purdue University, 1969; M.A. University of Toledo, 1971; Ph.D. Virginia Polytechnic Institute and State University, "An Ecologic-Economic Perspective for Coastal Zone Management."

Demitri Damianos, B.S. University of Rhode Island, 1971; M.S. Virginia Polytechnic Institute and State University, 1972; Ph.D. Virginia Polytechnic Institute and State University, "The Influence of Flood Hazards upon Residential Property Values."

Roger Maconick, B.A. Oxford University; M.A. Washington University; Ph.D. University of Wisconsin-Madison, "Optimal Allocation of a Renewable Resource: A Control Model of the Lake Superior Lake Trout Fishery."

James Paul Rathwell, B.S. Arizona State University, 1969; M.S. Oklahoma State University, 1972; Ph.D. Oklahoma State University, "Economic and Environmental Impact of Nitrogen Fertilizer Use."

Abdullah Ahmad Saleh, B.S. University of Pakistan, 1964; M.S. University of Missouri, 1970; Ph.D. Purdue University, 1974, "An Analysis of Consumer Food Expenditures and Consumption Waste."

James C. Wade, B.A. Abilene Christian College, 1967; M.A. University of Texas-Austin; Ph.D. Iowa State University, "Stream Sediment Movement, Water Quality and Agricultural Production: A Modeling Approach to Economic and Environmental Analysis."

Human Resource Development

Leon Elverne Abbas, B.S. Iowa State University, 1963; M.S. Montana State University, 1969; Ph.D. Oregon State University, "An Economic Analysis of Occupational Mobility: A Case Study of Oregon Commercial Fishermen."

Liu-Hsiung Chuang, B.A. National Taiwan University, 1961; M.A. National Taiwan University, 1965; M.S. Brigham Young University, 1968; Ph.D. Stanford University, "The Role of Human Capital in the Process of Economic Development: A Case Study of Japan."

Samuel T. Cooper, B.S., 1964; M.S. University of Missouri, 1965; Ph.D. University of Tennessee, "An Economic Analysis of the Training and Technology Manpower Training Program, Oak Ridge, Tennessee."

Labh Singh Hira, B.S. Punjab Agricultural University, India, 1969; M.S. Punjab Agricultural University, 1971; Ph.D. University of Missouri, "An Empirical Study of Advertised Retail Meat Prices in a Metropolitan Area."

George R. McDowell, B.S. University of Rhode Island, 1961; M.S. Cornell University, 1963; Ph.D. Michigan State University, "Whose Preferences Count? A Study of the Effects of Community Size and Characteristics on the Distribution of the Benefits of Schooling."

Kenneth W. Steen, B.S. University of Arizona, 1961; M.S. University of Arizona, 1968; Ph.D. Michigan State University, "Economic Impact of Multiple Unit Public Housing on Occupant, Proximate Neighbors and Public Services."

Ronald L. Thompson, B.A. University of Michigan, 1969; M.S. Michigan State University, 1972; Ph.D. Michigan State University, "Description and Analysis of Limited Resource Farmers in Michigan."

Gary Richard Vieth, B.S. University of Nebraska, 1967; M.S. University of Nebraska, 1969; Ph.D.

Oregon State University, "The Applicability of Selected Parameters of an Input/Output Model of One Region to Other Similar Regions: A Comparison of Small Rural Counties."

Hernan Zeballos-Hurtado, Ingeniero Agronomi, Universidad Mayor de San Simon; M.S. Universidade Rural de Minas Gerais; Ph.D. University of Wisconsin-Madison, "From the Uplands to the Lowlands—An Economic Analysis of Bolivian Rural-Rural Migration."

Marketing and Location

Dyaa A. Kamal Abdou, B.S. Cairo University, 1967; M.S. Iowa State University, 1973; Ph.D. Iowa State University, "The Impact of Separating Fed from Nonfed Beef in an Econometric Simulation."

Richard Svend Andersen, B.S. University of Alberta, 1969; M.S. University of Alberta, 1971; Ph.D. The Ohio State University, "The North American Market for Beef: Analysis of Future Market Dimensions and Competitive Relationships."

David G. Barton, B.S. Utah State University, 1967; M.S. Purdue University, 1970; Ph.D. Purdue University, 1974, "Physical Distribution System Design: An Application of Mixed Integer Programming to Meat Distributions."

Mario Del Fa, Law Degree University of Buenos Aires; M.S. University of Wisconsin-Madison; Ph.D. University of Wisconsin-Madison, "Economic and Legal Factors in the Marketing of Selected Agricultural Products in Argentina: The Generation of Transaction Costs."

Robert Freeman Glenn, B.S. Southwest State University, 1968; M.S. University of Missouri, 1970; Ph.D. University of Missouri, "A Farm Point Pricing System for Fluid Milk in Selected Midwestern Markets."

David Laurance Horton, B.S. Kansas State College, 1958; M.S. Mississippi State University, 1968; Ph.D. Mississippi State University, "An Economic Analysis of Alternative Price and Supply Arrangements for Grade A Fluid Milk in the United States."

William Sherman Jensen, A.B. University of Washington, 1957; M.S. Columbia University, 1959; J.D. University of California, 1965; Ph.D. Oregon State University, "A Market Structure Analysis of the Salmon Processing Industry."

Paul Eugene Kindinger, B.S. Michigan State University, 1970; M.S. Michigan State University, 1971; Ph.D. Cornell University, "Cost and Benefits of Marketing Services Provided by Western New York Apple Growers."

Sang-Woo Park, B.A. Seoul National University, 1964; M.A. Seoul National University, 1970; M.S. University of Minnesota, 1972; Ph.D. University of Minnesota, "Fertilizer Distribution in Korea."

Gaurisanker Raychaudhuri, B.A. Calcutta University, 1948; M.A. University of Delhi, 1952; Ph.D. Stanford University, "The Scope and Function of Commodity Futures in India (1954–70)."

Lynn W. Robbins, B.S. Michigan State University, 1968; M.B.A. Western Michigan University, 1971; M.S. Michigan State University, 1974; Ph.D. Michigan State University, "Warehousing Agricultural Inputs in Michigan: An Economics of Size and Location Analysis."

Supranee Rungdanay, B.S. Kasetsart University, 1967; M.S. North Dakota State University, 1971; Ph.D., The Ohio State University, "Economic Analysis of Ohio Farm Grain Selling Storage Practices."

Franz Schwarz, B.S. University of Vienna, 1969; M.S. University of Nebraska, 1972; Ph.D. University of Nebraska, "A Forecasting-Programming Method of Placement-Sales Decisions for a Beef Feedlot."

Daniel Robert Strang, B.S. Cornell University, 1966; M.S. Cornell University, 1968; Ph.D. Cornell University, "An Economic Analysis of the Sources and Magnitudes of Inefficiency in Bulk Milk Assembly in New York State."

William Anderson Thomas, B.S. North Georgia College, 1968; M.S. Clemson University, 1970; Ph.D. Clemson University, "Optimum Number, Size and Location of Fluid Milk Processing Plants in South Carolina."

Bruce John Walter, B.S. Rutgers University, 1963; Ph.D. University of California, Berkeley, "The Wholesale Pricing System for Refined Sugar."

William Neal Waterstreet, B.S. Northwestern University; M.S. University of Wisconsin-Madison; Ph.D. University of Wisconsin-Madison, "Impact of Strategic Innovations on the Structure of the Fluid Milk Industry."

Joseph E. Williams, B.S. New Mexico State University, 1965; M.S. New Mexico State University, 1967; Ph.D. Iowa State University, "Feeding-Marketing Decisions and the Value of the Price Forecast Information to the Cattle Feeder."

Natural Resource Economics

John Irette Bucy, B.S. University of Nebraska, 1953; M.S. University of Nebraska, 1959; Ph.D. University of Nebraska, "The Economic Feasibility of Producing Sulfuric Acid from SO_2 in Power Plant Stack Gases."

Lee A. Christensen, B.S. Iowa State University, 1961; M.S. University of Nebraska, 1966; Ph.D. Michigan State University, "An Economic and Institutional Analysis of Land Treatment as a Wastewater Management Alternative for Southeastern Michigan."

Daryl F. Kraft, B.S.A. University of Manitoba, 1968; M.Sc. University of Manitoba, 1968; Ph.D. Washington State University, "Economics of Agricultural Adjustments to Water Quality Standards in an Irrigated River Basin."

Chandi Charan Maji, B.S. Calcutta University, 1958; M.S. Indian Agricultural Research Institute; Ph.D. Iowa State University, "Intertemporal Allocation of Irrigation Water in the Mayurakshi Project (India): An Application of Deterministic and Chance-Constrained Linear Programming."

Angelos Pagoulatos, B.S. Universita Degli Studi di Roma, 1968; Ph.D. Iowa State University, "Major Determinants Affecting the Demand and Supply of Energy Resources of the United States."

Rodney M. Thomsen, B.S. University of Tennessee, Martin, 1971; M.S. University of Tennessee, 1972; Ph.D. University of Tennessee, "The Economic Effects of Agricultural Land-Use Management on Soil Erosion and Farm Income on the Obion-Forked Deer River Basin."

Carlos Federico Tobal, graduate, University of Buenos Aires, 1965; M.S. University of California, Berkeley, 1969; Ph.D. University of California, Berkeley, "Economic Analysis of Zanja del Tigre Project in Northwestern Argentina."

Roland Wentzel, B.S. California State Polytechnic College, San Luis Obispo, 1966; M.S. Oregon State University, 1968; Ph.D. University of California, Berkeley, "Aquaculture and the Conventional Fishery: The Salmon Case."

Production Economics and Management

Richard Melvin Adams, B.S. University of California, Davis, 1968; M.S. University of California, Davis, 1971; Ph.D. University of California, Davis, "A Quadratic Programming Approach to the Production of California Field and Vegetable Crops Emphasizing Land, Water and Energy Use."

Loukas Ananikas, B.S. Arist. University of Thessaloniki, 1963; M.S. Michigan State University, 1973; Ph.D. Michigan State University, "Potential Livestock Production Adjustments on Family Farms in Central Macedonia, Greece."

Alvin A. Bedel, B.S. Purdue University, 1966; M.S. University of Tennessee, 1970; Ph.D. University of Tennessee, "A Study of Potential Farm Growth and Survival for Representative Farms in West Tennessee."

Gary Dean Bruning, B.S. Kansas State University, 1967; M.S. Kansas State University, 1968; Ph.D. Kansas State University, "The Effect of Cropland Dispersion and Machinery Size on Crop Costs and Farm Returns on a Representative Northeast Kansas Farm."

Yie Lang Chang, B.S. Chung-Hsing University, 1963; M.S. Chung-Hsing University; Ph.D. Iowa State University, "Farm Size and Cost Functions in Relation to Machinery Technology in North Central Iowa."

Carl Chi-jiau Chen, B.A. North Carolina State University, 1958; M.A. Kent State University, 1969; Ph.D. Iowa State University, "Quadratic Programming Models of United States Agriculture in 1980: With Alternative Levels of Grain Exports."

William Arden Colette, B.S. Colorado State University, 1960; M.S. Cornell University, 1962; Ph.D. Iowa State University, "Impact of Water Right Constraints on the Regional Allocation of Agricultural Production."

Raphael Umera Igwebuike, B.S. Ibadan University, 1962; M.A. Williams College, 1966; Ph.D. Stanford University, "Barriers to Agricultural Development: A Study of the Economics of Agriculture in Abakaliki Area, Nigeria."

Bruce B. Johnson, B.S. University of Nebraska, 1966; M.S. University of Nebraska, 1968; Ph.D. Michigan State University, "Farmland Leasing as a Means of Resource Control in U.S. Land-Based Agriculture."

Yoshimi Kuroda, B.A. Ehime University, Japan, 1966; M.A. Kyushu University, Japan, 1968; Ph.D. Stanford University, "A Study of Japanese Farm Household Behavior in Production and Consumption in the Postwar Years."

Yung C. Lee, B.S. National Taiwan University, 1954; M.S. Michigan State University, 1968; M.A. Michigan State University, 1974; Ph.D. Michigan State University, "Adjustment in the Utilization of Agricultural Land in South Central Michigan with Special Emphasis on Cash-Grain Farms."

John J. Meek, B.S. University of Toronto, 1963; M.S. University of Guelph, 1968; Ph.D. Michigan State University, "Simulation of the Cattle-Calves Sub-Sector in a Developed Economy with Special Reference to the Canadian Cattle Herd."

Anton D. Meister, B.S. Canterbury University, 1969; M.S. Canterbury University, 1971; Ph.D. Iowa State University, "An Interregional Analysis of United States Agricultural Production under Alternative Water, Export, and Environmental Policies."

Thamrin Nurdin, B.S. University of Indonesia, 1961; M.S. University of New Hampshire, 1966; M.S. University of Hawaii, 1973; Ph.D. University of Hawaii, "Factors Affecting Farm Decision Making: A Case Study in West Sumatra, Indonesia."

Kwame (Daniel) Prakah-Asante, B.Sc. University of Science and Technology, Kumasi Ghana, 1968; M.Ex. Washington State University, 1970; Ph.D. Washington State University, "The Economies of Size of Food Crop Farms in the Mampong-Enura Agricultural District of Ghana."

Philip Lawrence Raikes, B.A. University of Oxford, 1961; M.A. Stanford University, 1964; Ph.D. Stanford University, "The Development of Mechanized Commercial Wheat Production in North Iraqw, Tanzania."

Marcelo M. Roguel, B.Sc. University of Philippines; M.Sc. Punjab Agricultural University; Ph.D. University of Wisconsin-Madison, "Analysis of the Economic Alternatives for the Large Size Dairy Farm in Wisconsin Agriculture."

Abdul Salam, B.S. West Pakistan University, 1967; Ph.D. University of Hawaii, "Economic Analysis of Fertilizer Application in Punjab Pakistan."

Gerald D. Schwab, B.S. Iowa State University, 1967; M.S. Michigan State University, 1969; Ph.D. Purdue University, 1974. "A Computerized Decision-Making Model for the Beef/Forage Enterprise."

William Edward Seale, B.S. University of Kentucky, 1963; M.S. University of Kentucky, 1969; Ph.D. University of Kentucky, "Factor Elasticities, Marginal Productivities and Returns to Scale for Selected Grain Farms in the Lower Ohio Valley Region of Kentucky."

Jhi Tzeng Shih, B.S. National Taiwan University, 1954; M.S. University of Hawaii, 1964; Ph.D. The Ohio State University, "Specification and Estimation of Farm Level Production Function from Combined Cross-Section Time Series Data in Taiwan."

Marlin G. Van Der Veen, B.S. University of Minnesota, 1966; Ph.D. The Pennsylvania State University, "Analysis of Interfarm Variety Rice Production in Cavite Province, Philippines."

Kenneth Neal Wegenhoft, B.S. Texas A&M University, 1967; M.S. Michigan State University, 1970; Ph.D. Oklahoma State University, "Micro Effects of Alternative Income Tax Management Strategies on Northwest Oklahoma Farms."

Donald L. Williams, B.S. West Texas State University, 1970; M.S. University of Tennessee, 1972; Ph.D. University of Tennessee, "An Economic Analysis of Beef Production in the Delta and Brown Soil Area of West Tennessee."

Public Policy and Programs

Nicolass W. Bouwes, Sr., B.S. University of Arizona; M.S. University of Wisconsin; Ph.D. University of Wisconsin-Madison, "An Economic Evaluation of Alternative Sewerage Pricing and Investment Practices: The Madison Metropolitan Sewerage District."

Maury E. Bredahl, B.S. North Dakota State University, 1966; M.S. North Dakota State University, 1969; Ph.D. University of Minnesota, "The Productivity and Allocation of Research at U.S. Agricultural Experiment Stations."

Marvin R. Duncan, B.S. North Dakota State University, 1957; M.S. North Dakota State University, 1972; Ph.D. Iowa State University, "A Programming Model for Analysis of Nonmetropolitan Hospital Services Systems and Application of the Model."

R. Samuel Evans, B.S. Virginia Polytechnic Institute and State University, 1964; Ph.D. Virginia Polytechnic Institute and State University, "Soybean Acreage Response: An Analysis of Price and Policy Impacts."

Allen C. Grommet, B.S. University of Illinois, 1969; M.A. Michigan State University, 1973; Ph.D. Michigan State University, "The Influence and Behavior of Interest Group Leaders in the Public Decision Process: A Model with Four Rural Applications."

Ioannis Karmokolias, B.S. University of Maine, 1968; M.S. Cornell University, 1970; Ph.D. Virginia Polytechnic Institute and State University, "An Analysis of Seasonal Home Development and Its Fiscal Impacts on Local Government."

Richard Lee Kilmer, B.S.A. Purdue University, 1965; M.S. Purdue University, 1967; Ph.D. The Ohio State University, "The Effect of Government Policy Instruments on Market Structure and Performance of the Ohio Fluid Milk Processing Industry."

John McKeon, B.S. University College, Dublin, 1968; M.A. Michigan State University, 1974; Ph.D. Michigan State University, "Farm Commodity Programs: Their Effect on Plantings of Feed Grains and Soybeans."

Philip L. Martin, B.S. University of Wisconsin-Madison; M.S. University of Wisconsin-Madison; Ph.D. University of Wisconsin-Madison, "The Estimation of Net Social Returns to Agricultural Research Expenditures."

Herbert Oliver Mason, A.B. Stanford University, 1971; Ph.D. University of California, Davis, "Decision-Making in Rural Local Government: A Case Study of Revenue Sharing."

Frederick James Nelson, B.S. University of Maryland, 1963; Ph.D. University of Minnesota, "An Economic Analysis of the Impact of Past Farm Programs on Livestock and Crop Prices, Production, and Resource Adjustments."

Kenneth C. Scott, B.S. Brigham Young University; Ph.D. Washington State University, "The Redistributional Consequences of Public Recreation Provision at the Potholes Reservoir—Columbia Basin Project, Washington."

William A. Sinclair, B.A. Hanover University, 1967; M.A. Indiana University, 1969; Ph.D. Michigan State University, "Intergovernmental Contracting for Police Patrol in Michigan: An Economic Analysis."

William Henry Smith, B.S. Black Hills State College, 1970; Ph.D. Kansas State University, "An Analysis of State Aid to Local School Districts for Pupil Transportation in Kansas with Proposals for Modification."

Regional Economics

Sanford B. Dooley, B.S. Oklahoma State University, 1966; M.S. Purdue University, 1968; Ph.D. Purdue University, "Factors Influencing Industrial Location Decisions in Micropolitan Areas."

Ronald James Dorf, B.S. University of Scranton, 1969; M.S. Iowa State University, 1971; Ph.D. Kansas State University, "An Analysis of Man-

ufacturing Location Factors for Communities 2,500 to 50,000 Population in the Northwest Central Region."

Jonathan G. Strauss, B.S. University of Bradford, 1968; M.A. University of East Anglia, 1969; Ph.D. Iowa State University, "Measuring Development: An Application to Two Rural Iowa Communities."

Research Methodology

Faqir Singh Bagi, B.S. Punjab Agricultural University, India, 1967; M.S. Punjab Agricultural University, 1970; Ph.D. The Ohio State University, "A Micro Economic Model of Farm Firm-Household Decisions: A Simultaneous Equation's Approach."

Luis Alberto Navarro Delgado, B.S. Universidad Austral de Chile, 1969; M.S. North Dakota State University, 1972; Ph.D. Oregon State University, "Best-Linear-Unbiased-Scalar Residuals Based Tests for Specification Errors."

Sterling Stipe, B.S. Auburn University, 1953; M.S. North Carolina State University, 1965; Ph.D. Michigan State University, "A Proposal and Evaluation of a Regional Input-Output Modeling System."

Rural Appraisal and Taxation

Arthur M. Heagler, B.S., University of Arkansas, 1955; M.S. University of Arkansas, 1956; Ph.D. Louisiana State University, "Economies of Farm Size in the Mississippi River Delta Area (Firm Adjustments Over Time to Exogenous and Endogenous Change)."

Edward Joseph Johnston, Jr., B.V.A. University of Massachusetts, 1964; M.S. University of Massachusetts, 1970; Ph.D. University of Connecticut, "Evaluation of Alternative Property Tax Systems to Reduce Disparity in Educational Expenditures and Property Tax Rates among Towns in Connecticut."

Socioeconomic Research

Mashal Khan, B.S. American University of Beirut, 1961; Dr. Agr. Technische Universität, Munich, 1967; M.A. Stanford University, 1968; Ph.D. Stanford University, "Socio-economic Factors in the Reduction of Human Fertility in the Islamic World with a Case Study of Iran."

William Otha Mizelle, Jr., B.S. North Carolina State University, 1967; M.S. North Carolina State University, 1970; Ph.D. Clemson University, "A Multivariate Analysis of South Carolina Consumer Attitudes toward the Food Industry."

Jose Prazeres Ramalho de Castro, B.S. Federal de Vicosa, 1956; M.S. Federal de Vicosa, 1969; Ph.D. Purdue University, 1974, "An Economic Model for Establishing Priorities for Agricultural Research and a Test for the Brazilian Economy."

Bruce A. Scherr, B.S. Rutgers University, 1970; M.S. Purdue University, 1972; Ph.D. Purdue University, 1974, "An Experimental Study of Decision-Making in Pricing Public Goods."

Theodore D. Thornton, B.S. Temple University, 1966; Ph.D. Iowa State University, "Patterns of Physician Utilization in the North Central Region of the United States."

Technological Change

Andres Bajuk, graduate, Contador Publico, University of Cuyo, 1967; M.S. University of California, Berkeley, 1972; Ph.D. University of California, Berkeley, "A Model of the Distribution of Income from Technological Change in Agriculture."

Chan Kil Chang, B.A. Korea University, 1964; M.A. Korea University, 1968; M.S. University of Hawaii, 1974; Ph.D. University of Hawaii, "Structure and Efficiency Measurement in Production: With Special Reference to Selected Agricultural Industries in Hawaii."

Trade

Susumu Hondai, B.S. Okayama University, 1968; M.S. Kyoto University, 1970; Ph.D. Michigan State University, "The Effects of Import Restrictions on Japanese Agricultural Production."

Julio A. Penna, B.S. University of Buenos Aires, 1968; M.S. University of Buenos Aires, 1970; Ph.D. Purdue University, 1974, "Optimal Storage and Export Levels of a Tradeable Product and Their Relationship with Annual Price Variability: The Case of Corn in Brazil."

Rubens Valentini, B.S. De Sao Paulo, 1969; Ph.D. Purdue University, 1974, "Technology and International Trade in Agricultural Products: A Test of Some Hypotheses."

Alberto Veiga, B.S. Rural University, 1956; M.S. Purdue University, 1965; Ph.D. Purdue University, 1974, "The Impact of Trade Policy on Brazilian Agriculture, 1947–1967."

Ram Prakash Yadav, B.S. Orissa University, 1965; M.S. Oregon State University, 1972; Ph.D. Cornell University, "An Econometric Model for the Foreign Trade Sector of India: 1960/61–1971/72."

Pesticides

Richard Edgar Howitt, B.S. Oregon State University, 1970; M.S. University of California, Davis, 1971; Ph.D. University of California, "Pesticide Externality Policy, An Optimal Control Approach."

Transportation

Marc A. Johnson, B.A. Kansas State Teachers College, 1970; M.A. North Carolina State University, 1971; Ph.D. Michigan State University, "Market and Social Investment and Disinvestment in Railroad Branch Lines: Evaluation Procedures and Decision Criteria."

Ph.D. Recipients by Institution

University of California, Berkeley

Andres Bajuk
Wen Shyong Chern
Sue Eileen Hayes
Kuo-Shuing Huang
William C. Nickel
Miguel Teubal
Carlos Federico Tobal
Bruce John Walter
Roland Wentzel
Trevor Young

University of California, Davis

Richard Melvin Adams
Richard Edgar Howitt
Herbert Oliver Mason
Robert Alexander Milligan

Clemson University

William Otha Mizelle, Jr.
William Anderson Thomas

University of Connecticut

Edward Joseph Johnston, Jr.

Cornell University

Bhupendra Maganlal Desai
Paul Eugene Kindinger
Radzuan Bin Abdul Rahman
Daniel Robert Strang
Stanley Robert Thompson
Ram Prakash Yadav

University of Hawaii

Chan Kil Chang
Thamrin Nurdin
Abdul Salam

University of Illinois

Chun-Lan Lee Liu
Soner Ogut

Iowa State University

Dyaa A. Kamal Abdou
Yie Lang Chang
Carl Chi-jiau Chen
William Arden Colette
Marvin R. Duncan
Mohamed H. El-Hurani
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Mark A. Lund
Chandi Charan Maji
Anton D. Meister
Lu Siong Ng
Angelos Pagoulatos
Jonathan G. Strauss
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Kansas State University

Roe Everett Borsdorf
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Ronald James Dorf
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Marc A. Johnson
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Alan Kent Reichert
Supranee Rungdanay
Jhi Tzeng Shih

Oklahoma State University

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Diego R. Londono
James Paul Rathwell
Kenneth Neal Wegenhoft

Oregon State University

Leon Elverne Abbas
Luis Alberto Navarro Delgado
William Sherman Jensen
Gary Richard Vieth

Pennsylvania State University

Oscar Goldman
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David G. Barton (1974)
William T. Boehm (1974)
Evonir Batista de Oliveira (1974)
Sanford B. Dooley
Richard J. Edwards (1974)
Ralph G. Lattimore (1974)
Ralph D. May
Julio A. Penna (1974)
Jose Prazeres Ramalho de Castro (1974)
Abdullah Ahmad Saleh (1974)
Bruce A. Scherr (1974)
Gerald D. Schwab (1974)
Donald R. Schwartz (1974)
Robert L. Thompson (1974)
Rubens Valentini (1974)
Alberto Veiga (1974)
Andres T. Vilas

Stanford University

Liu-Hsiung Chuang
Raphael Umera Igwebuike
Mashal Khan
Yoshimi Kuroda
Philip Lawrence Raikes
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Paul Kelly Steidlmayer

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Virginia Polytechnic Institute and State University

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Ioannis Karmokolias

Washington State University

Daryl F. Kraft
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Kenneth C. Scott

University of Wisconsin-Madison

Nicolass W. Bouwes, Sr.
Wilmer A. Dahl
Mario Del Fa
Leonel Guillermo Gonzalez
Roger Maconick
Philip L. Martin
Marcelo M. Roguel
William Neal Waterstreet
Hernan Zeballos-Hurtado

Obituaries

Charles Lamar Anderson

Charles Lamar Anderson, associate professor, Food and Resource Economics Department, University of Florida, died on 1 January 1976 at the age of 48. He is survived by his wife Betty Jane of Lake Alfred, Florida, son John Charles Anderson of Lake Wales, Florida, and daughter Catherine Louise Hester of Auburndale, Florida.

Anderson was born at Largo, Florida, on 14 May 1927. He received his B.S. degree in animal science in 1949 and an M.S. degree in agricultural economics in 1969 at the University of Florida. At the time of his death, Anderson was serving as Extension Farm Management economist at the Agricultural Research and Education Center, Lake Alfred, Florida.

Charlie Anderson was a practical economist and extension educator. His varied background as a ranch hand, ranch manager, pilot, lawman, and county agent, prior to joining the Food and Resource Economics Department in Extension Farm Management, contributed to his success in working with growers and ranchers. He was a genuine person, liked and respected by all those he contacted. The statewide tribute that has been paid to Charlie Anderson is a fitting testimony to his success as an extension educator.

Durward Brewer

Durward Brewer, Department of Agricultural Economics, University of Missouri-Columbia, died on 17 November 1975 in DeQueen, Arkansas, leaving as his survivor his devoted wife, Margaret, now living at Wickes, Arkansas. Brewer had never completely recovered from lung surgery, which took place in early 1975.

Born on 28 August 1925 near Rogers, Arkansas, Brewer was raised on a general farm and carried away with him a set of agrarian values that provided the basis for his philosophy of life. During World War II, he served for three years as an infantryman with combat experience in the European Theater.

After returning from the war, Brewer enrolled in college. He attended the University of Arkansas, Southern State College, and Henderson State Teachers College and was awarded a B.S. degree from Oklahoma A&M University in 1952. He earned his M.S. degree from the same school in 1953. Brewer completed his Ph. D. degree at the University of Missouri in 1960.

Most of Brewer's early research dealt with livestock marketing. He is better known, however, for his work in economic development, water-based recreation, land use, and taxation. His courses in economic development and welfare economics were always filled with examples from the world, for Brewer was a pragmatic man. One of the activities he enjoyed most was teaching an advanced undergraduate-graduate course in rural real estate appraisal. He enjoyed the thrill of enterprise and the market.

The students and colleagues of Durward Brewer remember him as one who valued individual accomplishment and who demonstrated those values in his own life through his many talents ranging from his profession to music to jewelry design to handmade musical instruments. He was an unusual man and the world will be a little lonelier place without him.

Robert B. Donaldson

Robert B. Donaldson, retired chairman of Agricultural Economics Extension, The Pennsylvania State University, died on 9 December 1975 in State College. He was 70. He retired from the University in 1970 after thirty-four years of service.

He received the B.S. in 1927 and the M.S. in 1934, both from The Pennsylvania State University, Rising through the ranks, he became chairman of the Extension Agricultural Economics and Rural Sociology section in 1952 and had administrative responsibilities for Extension Farm Management and Rural Sociology projects.

A specialist in the development of fruit and vegetable procurement systems, Bob advised regional and national chain stores on the design of efficient assembly methods and wrote a book, *Profitable Roadside Marketing*, which has become a guide for direct marketers of farm products. In 1963, he was a member of a team of U.S. specialists assigned to develop ways of improving import-export relations with the European Economic Community and Common Market countries, from which came a publication, *Toward Maintaining and Expanding Markets in Western Europe for U.S. Farm Products*.

Bob was a member of Alpha Gamma Rho, Gamma Sigma Delta, Sigma Phi Epsilon, and the American Agricultural Economics Association.

William I. Myers

William I. Myers died at his farm home near Ithaca, New York, on 30 January 1976 at the age of 84. His

death terminated a long and distinguished career in education and public service.

Myers was born at Lowman, New York, in 1891. He received the B.S. degree at Cornell University in 1914 and the Ph.D. in 1918. He was appointed assistant professor of farm management at Cornell in 1918 and promoted to professor of farm finance in 1920. He became head of the Department of Agricultural Economics in 1938 and Dean of the College of Agriculture in 1943. He retired from Cornell in 1959.

As a young faculty member, Myers specialized in farm management, farm finance, and cooperative organization and management. He taught classes, conducted research, directed graduate students, and participated in extension activities. He was an inspiring teacher and counselor. His classes were always crowded. Graduate students were anxious to work under his guidance. He was a busy man who organized his time and worked long hours but was always available to the numerous students, associates, farmers, and public officials who sought his counsel. Myers understood people and could respond with friendly advice and a pat on the back or a kick in the pants depending on which he considered would be most appropriate. The Cornell faculty elected him to the Board of Trustees of the University in 1939.

Myers took a leave of absence from Cornell at the depth of the depression in early 1933 to go to Washington to work on the reorganization and expansion of the federal farm credit agencies. He became deputy governor and, later in the year, governor of the newly created Farm Credit Administration. In these capacities, he was the principal architect and, as governor, the top administrator during the revitalization, reorganization, and expansion of the national cooperative farm credit system. At the same time, he administered emergency credit made available to millions of desperate farmers. The existing Federal Land Banks, which like many banks in 1933 had great difficulty in acquiring funds to make new loans, were strengthened so they could expand their mortgage lending to farmers. Later, the short-term Production Credit system and the Banks for Cooperatives were created and added. For more than forty years, these institutions have provided the means through which billions of dollars were borrowed from the money market and loaned to farmers and cooperatives of farmers. Their wide use and strong financial condition bears witness to the soundness of their design and operation and to the efforts of many dedicated people, especially to those of Myers. Myers resigned as governor in 1938 and returned to Cornell.

Myers was interested in agriculture abroad as well as in the United States and was an early advocate of U.S. assistance. His primary concern was in strengthening research and educational institutions and in expanding opportunities for advanced training. He exerted influence in these directions as a member of the board of the Rockefeller Foundation. He was directly involved in the creation and financing of the Agricultural Development Council and served on its board for many years. While dean at Cornell, he initiated the working relationships between the University of the Philippines and Cornell.

Myers's counsel and advice were sought by scores of public and private organizations. Within New York State, he served on dozens of commissions and committees whose functions were to advise the governor, legislature, and other public officials on policy issues. At the national level, he served three presidents—Roosevelt, Truman, and Eisenhower. In addition to his work as governor of the Farm Credit Administration, he advised President Roosevelt on other issues. He served President Truman on his Famine Emergency Committee and the Committee on Foreign Aid. He was chairman of President Eisenhower's National Agricultural Advisory Commission.

In addition to serving on the boards of the Rockefeller Foundation and Agricultural Development Council, he served as trustee or director of numerous other organizations, including the General Education Board, American Institute of Cooperation, Twentieth Century Fund, Carnegie Institute of Washington, Eisenhower Exchange Fellowships, New York State Association for Crippled Children, Elmira College, and Vassar College. He was a member of the board of directors of many corporations including the Federal Reserve Bank of New York, Mutual Life Insurance Co. of New York, Continental Can Co., Insular Lumber Co., U.S. Industrial Chemicals, New York State Electric and Gas Corp., AVCO Corp., Smith-Corona Marchant, Marine Midland Corp., and Grand Union.

Myers received many honors. In 1938, the American Farm Bureau cited him for "distinguished service to agriculture." In 1949, his Cornell Class of 1914 awarded him its "Outstanding Achievement Award." He was secretary of the American Agricultural Economics Association in 1927–31, was president in 1934, and was elected a fellow in 1958.

Throughout his productive career, Bill Myers remained a man of the soil committed to the welfare of rural people. He purchased a farm near Ithaca, New York, early in his career and lived on it almost throughout. Working on his farm and in his garden provided relaxation and firsthand experience with farming and its problems.

Myers was married to the former Marguerite Troxell. He is survived by three daughters—Elizabeth Martin of Cincinnati, Ohio, and Marian Kira and Margaret McElwee both of Ithaca, New York.

Ermine Lawrence Potter

Ermine Lawrence (Dad) Potter, professor emeritus and the first head of the Department of Agricultural Economics at Oregon State University, died in November 1975 in Corvallis, Oregon, at the age of 91. He was known throughout the state of Oregon for his work in the livestock industry.

Born in Missouri, Potter was graduated with honors from Montana State College in 1906. He earned a B.S. in agriculture and an M.S. from Iowa State University. He later studied at Stanford University and the University of California.

Potter joined the staff at Oregon State University in 1908 as an instructor in animal husbandry. He was head of the Department of Animal Husbandry from 1913 to 1932, when he became head of the new Department of Agricultural Economics. He retired in 1950 but worked on a part-time basis until 1961, going to Thailand in 1952 to lay the groundwork for a contract between Kasetsart University and Oregon State University.

Potter, who wrote many Oregon State University Experiment Station bulletins, was instrumental in founding the Withycombe Club for animal science students at OSU. He was active in the Oregon 4-H Horse Club program, and this service was recognized in 1971 when he received the Oregon 4-H Distinguished Service Award.

Potter helped to organize the Oregon Cattleman's Association and the Pacific International Livestock Exposition. He was a pioneer scientist in improving range and livestock management.

He is survived by his wife, Norma.

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A Bioeconomic Simulation Analysis of Regulating Groundwater Irrigation

Harry P. Mapp, Jr., and Vernon R. Eidman

This study develops a firm-level bioeconomic simulation model capable of stochastically determining yields for the major dryland and irrigated crops in the central basin of the Ogallala Formation as a function of soil moisture and atmospheric stress during critical stages of plant development. The model is used to evaluate three methods of regulating groundwater irrigation—no restriction, a quantity limitation, and a graduated tax per unit above the quantity limitation. Results differ for poor and adequate water situations but indicate the potential value of an educational program on timing of irrigation application to maximize net farm income.

Key words: bioeconomic simulation model, Ogallala, regulating groundwater irrigation.

The Ogallala Formation is a major unconsolidated aquifer providing irrigation water for much of the Great Plains. The formation extends from South Dakota to Texas, underlying parts of eastern Colorado, Nebraska, western Kansas, eastern New Mexico, the Oklahoma Panhandle, and the northern and southern high plains of Texas. The Arkansas River and Canadian River penetrate the formulation to bedrock, creating a separate hydrological subdivision known as the central basin of the Ogallala Formation. Water seepage into and from the aquifer is minimal. Thus, the central basin is essentially a closed container of water underlying a land area of approximately 17,500 square miles.

In recent years, increases in irrigated crop production and acre feet of water withdrawn from the central basin have been dramatic. With average annual recharge estimated to be only 0.27 million acre feet (Bekure), average annual overdraft currently exceeds 3 million acre feet. Continued overdraft leads inevitably to further declines in the water table and, other things being equal, to increases in pumping costs and reductions in the profitability of irrigated crop production. Eventually it will become uneconomical to pump water for irrigation purposes in some parts of the central basin. This implies resources once committed to irrigated production will revert to dryland farming. The adjustment from irrigated to dryland farming may result in serious primary and secondary reductions of income in the central basin. How severe the adjustments to the declining water table will be is determined in part by how fast the groundwater is depleted and in part by the actions taken to lessen the adverse effects of depletion. Consequently, the questions of concern to landowners, farm operators, businessmen, and policy makers alike are (*a*) what is the economic life of the water supply? (*b*) what will the economic adjustments in irrigated crop production entail? and (*c*) what can be done to mitigate the adverse effects of the declining water supply over time? The first two questions are addressed in an aggregate study by Bekure.[1] This study deals with the third.

Some policy makers and area leaders have suggested the appropriate method to mitigate the adverse effects is to meter wells and limit the amount of water use per year to the statu-

Harry P. Mapp, Jr., is an associate professor of agricultural economics at Oklahoma State University, Stillwater, and Vernon R. Eidman is a professor of agricultural and applied economics at the University of Minnesota, Minneapolis.

Journal Article No. J-3064 of the Oklahoma Agricultural Experiment Station. This research was conducted under Grant 14-01-0001-1539 from the Office of Water Resources Research and Oklahoma Agricultural Experiment Station Project No. 1358. The authors wish to thank Daryll E. Ray, Michael S. Salkin, and two anonymous reviewers of this *Journal* for their constructive comments on this manuscript.

[1] Drawing on earlier attempts by Kelso and Renshaw to evaluate groundwater as a stock resource and adapting methodology developed by Bellman and applied by Burt to groundwater reserves, Bekure projected the rate of groundwater withdrawal over the life of the aquifer and compared it to the rate of withdrawal that maximizes the net present value of the stock water resource. While his analysis indicates the projected rate of withdrawal will not exceed the rate maximizing the net present value, it does indicate significant adjustment to dryland farming will take place.

tory allocation of 1.5 acre feet per acre irrigated. This method of limiting water use would create some difficult planning problems for farmers in the area, given the variability of weather conditions.[2] The purpose of this study is to develop a bioeconomic model that can be used to evaluate the effect of alternative methods of water-use regulation at the firm level and to illustrate its use. The model is used to compute the firm-level effects of continued irrigation development on representative firms in two water-resource situations in the central basin.[3] In addition, the potential impact of regulating water use through a quantity limitation and a graduated tax per unit above the quantity limitation are evaluated. Variability in rainfall and evapotranspiration rates, which are of critical importance in determining crop yields, water pumped, and financial success in any year, are considered in the analysis to estimate the distribution of outcomes for each alternative simulated.

In the following section the problem of commonality of water use is discussed briefly and the rationale for the regulatory alternatives evaluated is presented.

Regulating Water Use

From a public viewpoint, maximization of long-run social benefits from the use of water represents the dominant goal of water-resource use (Timmons). This goal can be accomplished by efficient allocation of water among competing uses in present and future time periods. In the central basin of the Ogallala Formation, determination of the optimal allocation of the water resource at the firm level within and between production periods is complicated by problems of commonality and timing of water usage.

The problem of commonality of water-use leads to the divergence of private and social costs illustrated in figure 1 (Milliman).[4] The socially optimal allocation of water results when marginal social costs (*MSC*) are equated with marginal value product (*MVP*), resulting in use of *OA* acre feet of water. If the individual irrigator considers only marginal private costs (*MPC*) in the allocative process, water usage is expanded beyond the socially optimal level by amount *AD*.

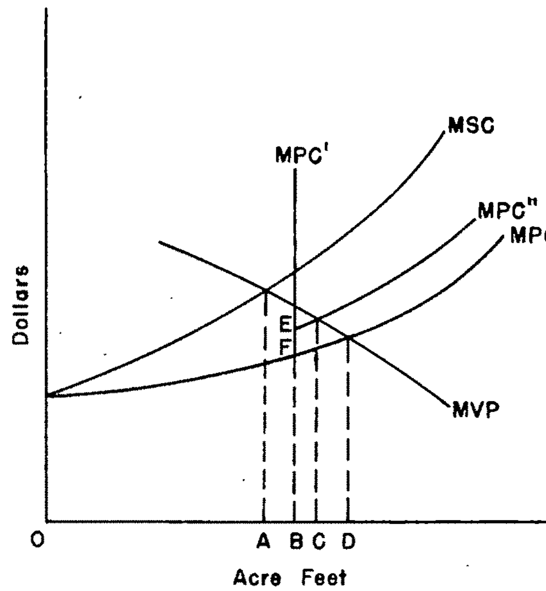

Figure 1. Effects of regulatory alternatives on the divergence of private and social costs

Several regulatory alternatives appear capable of more closely aligning marginal private and marginal social costs. For example, a quantity restriction equal to *OA* acre feet would result in a socially optimal allocation of water. A graduated tax equal to the difference between *MSC* and *MPC* for each acre foot of irrigation water pumped would likewise produce the socially optimal allocation.

This study is concerned with the firm-level impact of alternative measures society might take to align more closely marginal social and marginal private costs. No effort is made to define regulatory policies that equate private with social costs. The alternatives to no regulation evaluated in this study are selected because they appear to be more acceptable to irrigators, community leaders, and policy makers than regulatory methods that would

[2] The problem is one of deciding how many acres to irrigate given the uncertainty of water requirements. An irrigator that uses all of his allocation even ten days or two weeks before the end of the season may sustain large yield reductions, while irrigating fewer acres and "playing it safe" may result in the farmer foregoing a significant amount of income.

[3] The portion of the Central Ogallala Formation considered in this project includes part of two counties in southeastern Colorado, eight counties in southwestern Kansas, the three Panhandle counties of Oklahoma, and eight counties in the northern part of the Texas High Plains.

[4] A major cause of the divergence between private and social costs is the effect one irrigator may have on the pumping costs of other irrigators in the area. Removing water results in both increased pumping costs and reduced well yields for irrigators in the area of influence. Thus, one irrigator withdrawing large amounts of water relative to his neighbors' withdrawals may have a noticeable impact on their pumping costs resulting in the divergence of private and social costs illustrated for the individual in figure 1.

align more closely marginal private with marginal social costs.

At present, individual irrigators in the study area ignore the social costs of their actions. Irrigators are required to record water rights and space wells far enough apart to avoid obvious short-run conflicts but are operating in an environment relatively free of restrictions. This relative absence of water-use regulation is one alternative analyzed. Under this alternative, each farmer can withdraw the amount of water desired, limited only by the water-resource situation, pumping capacity, and the profitability of withdrawing water. The second alternative analyzed is a quantity limitation of 1.5 acre feet per acre of water rights. This method would require a significant reduction in pumping (approximately 25% below the current level) and has been suggested as an alternative by others dealing with the over-draft problem in the area (Kansas Water Resources Board).

In evaluating the effect of a tax on water use, the individual irrigator is allowed to pump without taxation until the quantity limitation is reached. Additional water is pumped only if the irrigator is willing to pay a tax of $0.50 per acre inch on each additional unit beyond the quantity limitation.

The three situations analyzed are depicted graphically in figure 1. Quantity *OD* represents the number of acre feet pumped by the individual who considers only private costs in the allocation decision. This "no restriction" situation is the first alternative simulated. Quantity *OB* represents the quantity of water pumped by an individual irrigator who equates MPC' and MVP under the quantity restriction and is the second alternative simulated. Imposing a per unit tax equal to, say, *EF* on each additional unit above *OB* would in effect force the irrigator to equate MPC'' and MVP, resulting in use of *OC* units of irrigation water. This is the third alternative simulated.[5]

Viewing the problem in a static setting (figure 1) is a useful manner to conceptualize the alternatives to be evaluated. However, an evaluation of the regulatory methods must consider the important dynamic elements of the problem. Within a year the uncertain weather and crop prices cause the expected *MVP* relationship to shift frequently between the time a farmer makes his planting decision and the time the final irrigation water is applied. Changes in the water table over time shift the marginal private cost curve. These dynamic aspects are incorporated into the model developed below.

Model Development

A firm-level bioeconomic simulation model is used as the basic tool in analyzing the three regulatory alternatives for two resource situations. Fundamental to the development of this model is the idea that timing of water application, rather than total amount applied, is of critical importance at the firm level. The operator observes the interaction of soil moisture and crop growth and development. The timing of an irrigation application and the quantity applied are determined by the operator on the basis of soil moisture and atmospheric stress conditions in relation to critical stages of plant development. His ability to respond to water-use restrictions depends upon his ability to reduce the quantity pumped but maintain crop yields by improving the timing of applications.

There is a growing literature documenting efforts to simulate bioeconomic systems. The work by Moore represents an early attempt by an economist to use simulation techniques to relate the incidence of moisture stress to crop yield under irrigated conditions. Moore argues that relative plant growth can be expressed as a function of available moisture depletion by inverting soil moisture release curves as they relate to available moisture depletion between field capacity and permanent wilting point. By using the moisture-release curve for a specific soil as an indicator of the relative growth rate of a plant grown on that soil, an index of

[5] The Oklahoma Water Resources Board has the power to order proper spacing of wells to insure an orderly withdrawal of water in relation to average annual recharge. It can also require metering of wells to record amounts pumped and can require persons to cease excessive withdrawals in reverse order of their water rights. It is empowered to restrict the rate of water use to one cubic foot of water per second for each seventy acres, or the equivalent thereof delivered on the land for a specified time in each year (Oklahoma Water Resources Board). By not indicating the intended length of "a specified time in each year," water use may be restricted to any amount desired by the Water Resources Board. Taxing water use does not fit within the current social or institutional structure of the study area. However, the graduated tax is evaluated in this study because it appears to be legally feasible and if administered appropriately would provide an economic incentive to conserve water. These by no means exhaust the regulatory possibilities. Additional restraints might include a lump sum tax on water use, a tax on each irrigation well, a limit on the number of wells per section or per farm, or a limit on well spacing. The possibility of importing water to sustain irrigated acreage could also be evaluated but was beyond the scope of this study. Time and resources did not permit evaluation of additional alternatives.

relative plant growth is derived. This index is multiplied by potential yield when water is not limited to obtain actual crop yield.

Flinn discusses models by Fleming and by Shaw that improve on Moore's assumptions by explicitly recognizing the interaction of soil moisture level and atmospheric demand for moisture on actual transpiration rates. These models relate plant growth on any day to the occurrence of moisture stress on that day. A moisture-stress day occurs whenever actual evapotranspiration falls below potential evapotranspiration.[6] Plant growth is assumed proportional to the number of stress days occurring during the growing season.

Implicit in these models is the assumption that the incidence and severity of stress alone reduces crop yields. Flinn argues both the incidence and severity of stress combine to determine crop yield and, in a recent model of corn development, relates growth in each time period to the incidence and severity of moisture stress in that period. Plant growth is assumed to decline in a linear fashion from the maximum rate of growth to no growth as the relative transpiration rate (ratio of actual to potential evapotranspiration) declines from 1 to 0.

The above models are designed to simulate soil moisture yield relationships for a single crop. Anderson and Maass present models to simulate the effects of temporary water shortages within the crop year on the final yield of several irrigated crops (Anderson, Anderson and Maass). Anderson and Maass divide the growing season into fourteen two-week periods, calculate quantities of water required by each crop during each period in typical irrigation sequences, and estimate the percentage reduction in crop yield assumed to occur if a specified irrigation is not applied. The model is applied to determine how best to allocate irrigation water among crops and farms participating in a water-distribution system under conditions of a limited supply of water. No attempt is made to model the soil-water– and atmospheric-stress–crop-yield relationships.

The model developed in this study determines yields on the basis of length and severity of both soil water and atmospheric stress in relation to critical stages of plant development for dryland and irrigated wheat, grain sorghum, and corn. The General Agricultural Firm Simulator developed by Hutton and Hinman is modified to simulate a representative farm for each resource situation. The major modification is the development of a production subset to simulate yields and irrigation water use in a stochastic framework.

The Production Subset

A basic assumption of the production subset is that under ideal soil water and atmospheric conditions some maximum potential yield may be achieved for each crop. In the event of plant stress, the amount of yield reduction depends upon the length and severity of soil-moisture stress and atmospheric stress in relation to the stage of plant development for each crop.[7] In implicit form, the yield reduction equation may be expressed as

$$YR_{ij} = f(SW_{ij}, AS_{ij}), \tag{1}$$

where YR = yield reduction, SW = soil-water level, AS = atmospheric stress, and i and j = the day and stage of plant development, respectively.

The level of soil water is a function of daily rainfall (RN_{ij}); evapotranspiration (EV_{ij}), which represents evaporative losses of moisture to plants and the atmospheric; and additions of moisture to the soil profile through irrigation applications (I_{ij}), or

$$SW_{ij} = g(RN_{ij}, EV_{ij}, I_{ij}). \tag{2}$$

Atmospheric demand for soil water is assumed to be a function of pan evaporation (PE_{ij}), or

$$AS_{ij} = h(PE_{ij}). \tag{3}$$

Thus, crop-yield reduction on day i of stage j is a function of the random variables rainfall, evapotranspiration, pan evaporation, and irrigation application rate.

The model requires daily estimates of soil water level and atmospheric demands upon the plants. A soil water balance is constructed, based on the findings and ideas pre-

[6] Potential evapotranspiration refers to the quantity of water that would be evaporated and transpired under adequate soil water conditions for a particular crop and stage of plant development. Measures of potential evapotranspiration are frequently related to pan evaporation. Actual evapotranspiration refers to the amount of soil water actually transpired and evaporated. For a given plant and stage of development, actual evapotranspiration is a function of potential evapotranspiration and soil water conditions.

[7] The terms moisture stress and atmospheric stress are used to describe plant stress. Plant stress occurs whenever demands upon the plant from the atmosphere exceed the ability of the plant's root system to draw water from the soil. Effects of inadequate soil moisture and severe atmospheric conditions are considered separately in this analysis because of the extremely arid conditions in the study area.

sented by Van Bavel, Thornthwaite, Thornthwaite and Mather, Holmes and Robinson, Denmead and Shaw, and Ligon, Benoit, and Elam, to provide daily soil-water levels adjusted to reflect additions due to rainfall and irrigation applications and subtractions due to evapotranspiration. Daily rainfall events are generated from discrete empirical probability distributions for each of fourteen two-week periods throughout the growing season. Daily pan evaporation values are generated from fourteen log-normal distributions of pan evaporation (Mapp).

Calculation of soil water on a daily basis permits consideration of the effects of soil water and atmospheric demands on crop yields on a daily basis. The combined effects of soil-water stress and atmospheric stress on yield reductions is assumed to be additive, due to lack of information regarding their interaction. Combining equations (1), (2), and (3), the yield reduction equation may be stated in explicit form as

$$(4) \qquad YR_{ij}^k = \theta_j^k SWD_{ij} + b_j^k(P_{ij} - P_a),$$

where YR_{ij}^k = yield reduction for day i, stage j, and crop k; θ_j^k = the coefficient reflecting yield reduction in units per day resulting from adverse soil water conditions; SWD_{ij} = soil water depletion in inches; b_j^k = the coefficient reflecting yield reduction in units per day due to severe atmospheric demands upon the plant; P_{ij} = pan evaporation in inches; and P_a = a critical pan evaporation level at or below which no yield reductions occur that are directly attributable to severe atmospheric conditions. The coefficients θ_j and b_j were estimated for three stages of plant development for grain sorghum, four stages for wheat, and five stages for corn.[8] The stages of development and soil water and atmospheric-stress coefficients for each crop are presented in table 1.

The production subset calculates the daily soil moisture balance for each crop block (field) included on the representative farm. The relation in equation (4) is used to calculate yield reductions for each day of the growing season for the crop produced on each crop block (field). The sum of the daily yield reductions is subtracted from the potential yield to obtain the yield for the crop block (field).

The production subset is quite flexible. It is used to calculate yields for dryland production as well as a variety of irrigation levels. The number and size of crop blocks (fields) can be adjusted to achieve the desired degree of realism concerning the precise time of irrigation and its effect on yield of the crops produced.

The Resource Situations

The resource situations were defined based on the saturated thickness of the Ogallala Formation. Saturated thickness is a critical determinant of both the quantity of water in storage and the yield of the aquifer in gallons per minute (GPM). The analysis was completed for

[8] Coefficients were synthesized and verified rather than estimated using sophisticated mathematical procedures. While it may be argued that mathematical estimation is preferable, lack of data for the study area eliminated this alternative. The coefficients, although probably not as accurate as implied by the use of two decimal places, nevertheless represent the best available estimates until more experimentation is performed and more data are available.

Table 1. Soil Water and Atmospheric Stress Coefficients for Grain Sorghum, Wheat, and Corn by Stages of Development

Grain Sorghum[a]	Preboot	Boot-Heading	Grain Filling
Soil water (θ_j)	0.30	2.04	1.27
Atmospheric (b_j)	1.30	1.65	1.50

Wheat	Preboot	Boot	Flower	Milk
Soil water (θ_j)	0.45	1.02	1.55	1.66
Atmospheric (b_j)	0	1.10	1.20	1.50

Corn	Vegetable 1	Vegetable 2	Silking	Milk	Dough
Soil water (θ_j)	0.20	1.15	3.05	1.14	1.57
Atmospheric (b_j)	0.10	0.60	1.60	0.40	0.10

[a] The soil water stress coefficient of 0.30 for preboot stage of grain sorghum development denotes that as soil water approaches wilting point, yield reduction approaches 0.30 bushels per acre per day. The atmospheric stress coefficient of 1.30 indicates that under the most severe atmospheric conditions yield reduction approaches 1.30 bushels per acre per day.

each of two saturated thicknesses to obtain information on the effect of this factor on the analysis. Resource situation 1 has a saturated thickness of 100 feet representing the "poor water" situation within the study area. Resource situation 2, with saturated thicknesses averaging 325 feet, represents the "adequate water" situation in the study area. Each resource situation is characterized by a representative farm firm, and the effects of continued pumping on saturated thickness and well yield are simulated through time.

Surveys from seventy-eight randomly sampled farm operations were utilized to develop an organization for the representative farm (table 2). Assumptions concerning the machinery complement, overhead costs, labor requirements, prices, and irrigation equipment are given elsewhere (Mapp).

Table 2. The Organization for Representative Cash Grain Farm, Central Ogallala Formation

	Acres
Irrigated grain sorghum	170
Field G1 (80)	
Field G2 (40)	
Field G3 (30)	
Field G4 (20)	
Irrigated wheat	85
Field W1 (65)	
Field W2 (20)	
Irrigated corn	60
Field C1 (40)	
Field C2 (20)	
Dryland grain sorghum	30
Field G5 (30)	
Dryland wheat	85
Field W3 (85)	
Total	430

Irrigation Strategies and Behavioral Assumptions for Unrestricted Pumping

The irrigation operator is assumed to know the critical water-use periods for each crop and which of the several crops requiring water during a specific period has the highest use value for the irrigation water available. He is assumed to apply water during a specific period first to the crop that has the highest use value (marginal value product) for that unit of irrigation water. Once that crop has received an irrigation application, the crop or crop block having the highest marginal value product for the next unit of irrigation water receives the next irrigation application. The operator may switch crop priorities from one part of the growing season to another in response to changes in the value of irrigation water among crops.

To simulate the decision environment, the growing season is subdivided into five irrigation periods based on critical stages of plant development for grain sorghum, wheat, and corn. A crop calendar (table 3) shows the period when two or more crops are in direct competition for irrigation water and the irrigation priorities.

The decision maker bases the application of irrigation water upon the level of soil water. The decision to irrigate is made when the level of soil water falls below a critical level of available soil water (50% in this analysis). The

Table 3. Delineation of Critical Stages of Plant Development and Irrigation Priorities

	May	June	July	August	September
	1 7 15 23 31	6 13	2 16 18	4 9 24	1 15 22 30
Grain sorghum[a]	Preplant		Preboot	Boot-Heading	Grain-Filling
Wheat	Preboot Boot Flower Milk				Preplant
Corn[b]	Preplant Vegetative 1	Vegetative 2	Silking	Milk Dough	

Critical periods	May 1–15	May 16–June 5	June 6–Aug. 4	Aug. 5–Sept. 15	Sept. 16–30
Irrigation priorities[c]	G,W,C	W,C,G	C,G	G,C	G,W
Pumping days	14	20	56	39	14

[a] No stage name is given to grain sorghum between preplant irrigation applications and preboot stage. Moisture stress during this period has little effect if moisture is adequate during subsequent stages of development.
[b] Plant emergence occurs between May 1 and 7.
[c] Irrigation priorities G, W, and C represent grain sorghum, wheat, and corn, respectively. All of the crop listed first in a critical period is irrigated before the second- or third-priority crops.

irrigation priorities in table 3 indicate the order in which soil water values are checked. A complete discussion of the development of the crop calendar and irrigation strategies is presented in Mapp et al.

Three water-use alternatives are simulated. The "no policy" alternative follows the above procedure to allocate water from the one well with an initial capacity of 900 GPM. Irrigators in resource situation 1 face declining well yields over the twenty-year simulated time period. When the capacity of the system falls below 750 GPM in a given year, the irrigator is assumed to drill a new well at the end of that year. When the operator has three irrigation wells, his response to declining well yields is to reduce the number of irrigated acres. An irrigated crop block is converted to dryland in the year following receipt of net returns less than the expected net returns for the best dryland alternative.[9]

Behavioral Assumptions for the Quantity Limitation and Graduated Tax

Imposing either of the regulatory alternatives is expected to induce irrigation operators to adopt strategies that increase expected returns per acre inch of water applied. This is made operational by imposing maximum limits on the amount of water that will be applied on each crop in each of the five periods. Decisions on the application of irrigation water under the quantity limitation are similar to the decisions under unrestricted pumping except that the maximum limits are imposed.

The maximum limits by period are also imposed in simulating the irrigators' response to the graduated tax alternative. When the limit on tax-free water has been used (1.5 acre feet per acre), the irrigator is assumed to apply an additional irrigation only if the additional expected returns are greater than the sum of the variable pumping cost and the tax payment.

The unrestricted pumping alternative, a quantity limitation alternative, and graduated tax alternative are simulated over a twenty-year period and replicated fifteen times.[10] The results of these simulation runs are discussed in the following section.

Results

Amount of Water Pumped

The effects of the three water-use alternatives on the amount of water pumped are presented in table 4 for the two resource situations. Consider the values for resource situation 1 in the top one-half of the table. From year 1 through year 10, the mean value of total acre inches pumped under unrestricted pumping exceeds acre inches pumped under the quantity limitation of 1.5 acre feet per acre and graduated tax of $0.50 per acre inch above the quantity limitation. During the same period, the irrigator paying a graduated tax for each acre inch above the quantity limit finds it profitable to pump water in excess of the quantity limitation every year except two. A third irrigation well is usually added by year 10 under the unrestricted alternative, by year 11 under the graduated tax alternative, and by year 12 under the quantity limitation. This reflects the different rates of pumping under each alternative in early years of the simulated time period.

From year 12 to year 20, there is a complete change in the pattern of total acre inches pumped under the three water-use alternatives. Greater withdrawals in early periods under the unrestricted alternative reduce irrigation system capacity to such an extent that the lowest mean total acre inches pumped from year 12 through 20 is by the unrestricted irrigator. Water use under the graduated tax alternative is somewhat larger over the period than for the unrestricted alternative. The largest rate of water use during the period occurs under the quantity restriction in which

[9] The interrelationships among water-use policy, water-use rates, investment in irrigation equipment, and reduction in irrigated acreage create a rather complex decision environment. In this analysis, simulation of the response of irrigators to declining well yields is based on actions of good managers in the study area as observed by irrigation and farm management specialists familiar with the area.

[10] Each simulation run (replicate) covered a twenty-year simulated time period. A twenty-year period was selected based on the analysis of Bekure indicating the likelihood of economic exhaustion in some portions of the study area within twenty years. During each year of the simulation run, a set of daily rainfall and pan evaporation events were generated, crop yields were determined on the basis of soil water and atmospheric stress, crops were harvested and sold, decisions were made to replace fully depreciated machinery, taxes and family consumption expenditures were deducted, and the ending financial situation was calculated. Each replication traces the firm through an entirely different set of random weather events. Model validation received considerable attention. Coefficients developed for the crop response model were evaluated by agronomists, soil physicists, and agricultural engineers. The behavioral aspects of the model were developed in conjunction with farm management and irrigation specialists familiar with practice utilized by the better managers in the study area. Model validation is treated by Mapp et al. While many replications were utilized in validating the model, available resources limited the analysis to fifteen replications.

water is not depleted as rapidly in earlier years of the simulated time period as for the other two alternatives.

The figures in the bottom half of table 4 reflect total acre inches pumped for resource situation 2. The number of acre inches pumped under the unrestricted alternative exceeds total acre inches pumped under the graduated tax alternative by a wide margin. Water use in the graduated tax alternative also exceeds water use under the quantity restriction by a wide margin. In addition, there is considerably more variability in water use associated with the unrestricted alternative. As expected, of the three alternatives, the quantity restriction has the smallest variation in total acre inches pumped.

Relative Rates of Water Withdrawal

Table 4 also summarizes saturated thickness remaining at the end of the twenty-year simulation run. For resource situation 1, the mean values of feet of remaining saturated thickness are 35.84 for unrestricted pumping, 38.37 for quantity restriction, and 37.72 for graduated tax alternatives. Water is used at different rates for each alternative, but regardless of the alternative utilized the ending position is approximately the same. The individual farmer either completely returns to dryland farming or stabilizes at about eighty acres of irrigated grain sorghum and attempts to spread fixed costs of the irrigation system over forty to sixty-five acres of irrigated wheat during portions of the crop year not devoted to intensive summer irrigation of grain sorghum. From the standpoint of the underground water supply, each of the alternatives simulated leads to economic exhaustion within resource situation 1 in about twenty years, given the assumptions of the model.[11]

Table 4 also presents feet of remaining saturated thickness for each water-use alternative for resource situation 2. Mean levels of saturated thickness are 235.02, 251.81, and 245.61 for the unrestricted, quantity restriction, and graduated tax alternatives. The average feet decline in saturated thickness are 89.97, 73.19, and 79.39 for the three water-use alternatives, respectively.

[11] The Wilcoxon Matched Pairs, Signed Ranks Test (Siegel) was used to test each set of mean values of total acre inches pumped under the three institutional alternatives. These tests revealed no differences among the distributions at the 5% level of significance.

Table 4. Summary of Total Acre Inches of Water Use

	Year																				Remaining Feet of Saturated Thickness
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
Resource Situation 1, No Restrictions																					
Mean	5,805	5,550	6,911	7,385	7,061	6,585	6,446	5,935	6.006	6,218	5,898	5.361	4,610	4,028	3,280	2,859	2,486	2,208	1,963	1,324	35.84
Maximum	6,699	6,039	8,305	9,265	8.229	7,607	7,092	6,704	7,568	7,492	6,506	6,195	5,161	4,949	4,143	3,827	3,419	2,739	2,361	2,202	37.53
Minimum	2,852	4,225	1,923	4,704	4,454	5,369	5,605	5,167	4,981	4,490	4,646	4,136	3,261	2,858	2,561	1,760	1,819	903	0	0	33.42
Resource Situation 1. Quantity Restriction																					
Mean	5,387	5,466	5,704	5,661	5,599	5,656	5,687	5,674	5,566	5,339	5,601	5,644	5,244	4,817	3,990	3,561	3,116	2,559	2,489	1,791	38.37
Maximum	5,710	5,708	5,741	5,739	5,728	5,730	5,714	5,716	5,715	5,694	5,717	5,712	5,709	5,701	5,097	4,442	4,000	3,621	3,173	2,975	41.57
Minimum	2,851	4,227	5,636	5,257	4,188	5,084	5,673	5,394	4,600	4,024	4,583	5,295	3,623	2,970	2,939	1,802	1,988	1,157	1,796	0	36.08
Resource Situation 1. Graduated Tax																					
Mean	5,549	5,429	6,371	6,045	6,144	6,040	6,115	5,878	5,514	5,580	5,954	5,659	4,836	4,266	3,533	3,274	2,854	2,508	2,483	1,447	37.72
Maximum	6,072	5,842	7,118	7,216	7.109	6,732	6,426	6,312	6,111	6,604	6,488	6,373	5,652	5,300	4,364	4,263	3,790	3,271	5,705	2,529	40.97
Minimum	2,722	4,226	5,500	1,799	4,530	5,094	5,519	5,085	4,396	4,390	4,572	4,481	3,315	2,867	2,791	1,894	2,066	1,087	0	0	34.67
Resource Situation 2. No Restriction																					
Mean	6,692	6,711	6,835	6,777	6.861	6,743	7,065	7,043	6,900	6,662	6,948	7,181	6,963	7,233	6,871	7,061	6,974	6,843	6,972	6,823	235.03
Maximum	7,813	7,745	7,474	7,862	7,921	7,921	7,670	7,865	7,742	7,865	7,925	7,835	7,802	7,895	7,685	7,835	7,865	7,925	7,791	7,862	240.62
Minimum	3,007	4,297	5,602	4,770	3,911	5,325	6,142	5,878	5,051	4,740	4,950	5,681	4,005	5,947	4,567	4,791	4,860	3,352	5,130	5,227	230.49
Resource Situation 2, Quantity Restriction																					
Mean	5,472	5,560	5,679	5,599	5,636	5,643	5,699	5,696	5,642	5,597	5,638	5,691	5,537	5,673	5,590	5,627	5,637	5,545	5,659	5,665	251.81
Maximum	5,730	5,722	5,722	5,722	6,639	5,722	5,722	5,722	5,722	5,722	5,722	5,722	5,716	5,716	5,692	5,715	5,722	5,722	5,723	5,722	254.26
Minimum	3,008	4,297	5,490	4,770	3,911	5,130	5,673	5,672	5,051	4,545	4,950	5,677	4,005	5,490	4,567	4,791	4,860	3,352	5,230	5,160	250.82
Resource Situation 2, Graduated Tax																					
Mean	5,875	6,010	6,035	6,070	5,931	6,000	6,249	6,157	6,107	5,960	6,131	6,274	6,173	6,209	6,073	6,209	6,161	6,032	6,099	6,130	245.61
Maximum	6,795	6,750	6,495	6,780	6,735	6,735	6,660	6,735	6,735	6,570	6,735	6,795	6,735	6,735	6,645	6,645	6,645	6,645	6,795	6,645	249.19
Minimum	2,722	4,297	5,265	4,695	3,911	5,130	5,850	5,402	4,699	4,320	4,950	5,535	3,915	5,310	4,477	4,791	4,860	3,352	4,950	5,160	242.88

Note: The values in this table are based on fifteen replications. The values for each replication are reported by Mapp.

Net Farm Income

Mean values of net farm income for years 5, 10, 15, and 20 for each resource situation are presented in table 5. For resource situation 1, net farm income under the graduated tax alternative exceeds net farm income under the unrestricted pumping alternative during every year except year 5. Beginning with year 6, net farm income under the graduated tax alternative exceeds net farm income under unrestricted pumping by a wide margin. Several interrelated factors create this phenomenon. The unrestricted irrigator tends to operate his irrigation system at its maximum capacity. In responding to soil moisture levels throughout the growing season, the tendency is to attempt to maximize yields rather than profits. Thus, irrigation use is pushed beyond the most profitable level. Also, irrigators facing the graduated tax pump less water during earlier years, preserving more saturated thickness and an ability to achieve more timely irrigation in relation to plant needs during critical periods of development in later years. More timely applications lead to higher final crop yields for the same amount of irrigation water. Since pumping costs rise more slowly, net returns per acre and net farm income are higher.

Mean net farm income for resource situation 2 appears in the bottom half of table 5. The moderate increase in net farm income over time reflects gradual retirement of chattel and real estate debts and accumulation of cash. The level of farm income under the graduated tax alternative is only slightly less than under unrestricted pumping. Both unrestricted pumping and the graduated tax alternative have levels of net farm income that greatly exceed the level under the quantity restriction.[12]

Discounting Net Income Streams

The streams of net farm income are discounted to their present value at several interest rates. Present values of net farm income

[12] The Wilcoxon Matched Pairs, Signed Rank Test reveals a statistically significant difference between mean values of acre inches pumped and net farm income for the unrestricted pumping versus quantity limitation alternatives, unrestricted pumping versus graduated tax alternatives, and graduated tax versus quantity limitation alternatives.

Table 5. Net Farm Income and Its Present Value for Alternative Water-Use Regulations

	Year				Present Value	
	5	10	15	20	8%	5%
			Resource Situation 1, No Restriction			
Mean	15,045	11,324	7,719	2,183	101,264	123,421
Maximum	23,876	20,037	18,372	11,924		
Minimum	9,571	2,996	2,466	−8,109		
			Resource Situation 1, Quantity Restriction			
Mean	12,270	11,899	5,586	2,447	89,695	109,469
Maximum	23,559	22,296	15,133	13,910		
Minimum	4,518	2,153	−2,909	−10,007		
			Resource Situation 1, Graduated Tax			
Mean	14,966	13,368	9,270	5,056	112,843	139,711
Maximum	24,074	23,625	20,608	17,229		
Minimum	8,610	5,560	3,036	−3,920		
			Resource Situation 2, No Restriction			
Mean	16,754	18,563	18,548	19,293	155,056	200,776
Maximum	26,548	26,076	27,602	25,059		
Minimum	11,030	10,998	13,451	13,491		
			Resource Situation 2, Quantity Restriction			
Mean	13,440	15,079	14,451	15,632	124,868	160,733
Maximum	24,923	25,220	23,891	22,632		
Minimum	6,450	6,979	8,898	10,572		
			Resource Situation 2, Graduated Tax			
Mean	16,383	18,456	18,036	19,020	151,760	196,366
Maximum	26,549	26,617	27,520	24,621		
Minimum	10,173	11,051	11,608	12,329		

Note: The values in this table are based on fifteen replications. The values for each replication are reported by Mapp.

for each regulatory alternative at 5% and 8% interest rates for resource situations 1 and 2 are presented in table 5.

Major implications of the analysis are not altered by consideration of the present values of alternative streams of income. For resource situation 1, the present value of net income is greatest for the graduated tax alternative. This finding is not surprising since net farm income under the graduated tax alternative exceeds net farm income under the unrestricted pumping alternative during every year but one. The present value of net farm income under unrestricted pumping exceeds that under the quantity limitation. Net farm income under unrestricted pumping greatly exceeds net farm income under a quantity restriction during early years of the simulated time period. During early years, the discount factor is small and discounted values of net farm income is large. It is only during year 10 and years 17, 18, 19, and 20 that net farm income under a quantity restriction slightly exceeds net farm income under unrestricted pumping. In late periods, the discount factor is large, and contributions to the present value of net farm income are small.

For resource situation 2, the present value of net farm income under unrestricted pumping exceeds present values under both graduated taxation and a quantity limitation. This result is expected since the level of net farm income under unrestricted pumping exceeds that under the graduated tax every year except year 1. Since the levels of net farm income remain homologous over time, the present values are nearly the same. Present values of net farm income under both unrestricted pumping and graduated taxation exceed the present value of net farm income under the quantity limitation. This finding is consistent with the significant differences found between distributions of net farm income under unrestricted pumping and graduated taxation when tested against the distribution under the quantity restriction.

Net Worth

A summary of ending net worth for the two resource situations in years 5, 10, 15, and 20 under unrestricted, quantity restriction, and graduated tax alternatives is presented in table 6. For resource situation 1, ending net worth is greatest under the graduated tax alternative followed by unrestricted pumping and the quantity limitation. However, for resource situation 2, unrestricted pumping results in the highest ending net worth followed by the graduated tax and the quantity limitation.

Table 6. Summary of Net Worth For Alternative Water-Use Regulations

	Year			
	5	10	15	20
	Resource Situation 1, No Restriction			
Mean	135,829	155,568	152,979	135,555
Maximum	160,580	182,686	201,896	214,774
Minimum	125,187	122,706	84,606	36,537
	Resource Situation 1, Quantity Restriction			
Mean	129,165	140,430	133,937	115,617
Maximum	156,761	172,615	190,856	205,332
Minimum	114,607	98,546	61,469	2,198
	Resource Situation 1, Graduated Tax			
Mean	136,827	160,349	166,641	161,676
Maximum	161,736	187,048	214,434	235,767
Minimum	125,491	125,214	106,036	66,865
	Resource Situation 2, No Restriction			
Mean	143,829	178,998	221,762	274,723
Maximum	164,767	199,919	251,790	318,245
Minimum	134,297	152,712	182,991	223,685
	Resource Situation 2; Quantity Restriction			
Mean	135,085	155,118	178,031	208,230
Maximum	163,443	184,875	222,820	273,540
Minimum	121,293	114,120	119,606	125,291
	Resource Situation 2, Graduated Tax			
Mean	143,491	177,506	217,774	268,714
Maximum	166,971	200,388	255,038	323,366
Minimum	132,114	144,216	171,583	205,703

Note: The values in this table are based on fifteen replications. The values for each replication are reported by Mapp.

Summary and Implications

This study developed a firm-level bioeconomic simulation model capable of stochastically determining yields for the major dryland and irrigated crops of the study area as a function of soil moisture and atmospheric stress during critical stages of plant development. The model was used to simulate three alternative means of regulating water use in the central basin of the Ogallala Formation. A "no restriction" alternative, a limitation on the quantity of water pumped, and a graduated tax above the quantity limitation were simulated for poor and adequate water-resource situations.

Policy implications differ somewhat for the

two resource situations. In the poor water situation, economic exhaustion appears likely in about twenty years unless a policy limiting water use to much less than 1.5 acre feet per acre is adopted. Policy makers interested in conserving water may be indifferent as to whether pumping continues unrestricted or is reduced by applying a limitation. However, this analysis indicates the more rational water use under the graduated taxation alternative results in a significantly greater level of net farm income than under either unrestricted pumping or a quantity limitation. For this reason, the policy maker might prefer imposition of a graduated tax on water use.

Restriction of water use for resource situation 2 has a different impact and somewhat different policy implications. Unrestricted pumping results in the greatest water use and highest level of net farm income. The analysis indicates that the graduated tax alternative reduces water use significantly while maintaining a level of net farm income comparable to that under unrestricted pumping. Nevertheless, individual irrigators are expected to prefer unrestricted pumping.

The quantity limitation may seem preferable to policy makers because it reduces water-use rates by the largest amount, requires fewer changes in the legal framework, and is easier to administer. However, this alternative provides the lowest level of net farm income with the greatest relative variability.

The analysis from these two situations indicates that the taxation alternative is probably preferable from the individual irrigator's standpoint to the quantity limitation. If it is essential to have the taxation alternative limit water use to about the same level as the quantity restriction, the tax could be imposed at a somewhat lower level, say, 1.3 or 1.4 acre feet, to achieve the desired result. However, imposition of the graduated tax requires significant changes in the legal and institutional framework. These changes may be both difficult to enact and administer.

Additional work is needed to evaluate other strategies of allocating water under both quantity and taxation alternatives. However, the variability in pumping requirements under the unrestricted and taxing alternative suggests that it will be very difficult to devise an irrigation strategy under the quantity limitation having comparable returns to a taxing alternative that uses approximately the same amount of water.

Perhaps the clearest implication of the analysis is the need for an educational program on allocating irrigation water to maximize net farm income in both resource situations. The model discussed could be used to illustrate the advantages of following such rules on typical and/or actual farms. An educational program of this nature would be more palatable to individual operators in the area than either a quantity restriction or a graduated tax on water use.

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A Dynamic Regional Model for Evaluating Resource Development Programs

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The purpose of the paper is to describe and demonstrate the usefulness of a dynamic regional economic model for evaluating resource development programs. The model results indicate that without development programs land may constrain livestock production after 1976. The growth in crop production is demand determined and will not exceed available land. A labor requirement of 15,400 man-years is projected for 1976 with 2,600 unutilized. Output and income distribution effects of drainage, training, and land-clearing development programs are assessed for the Interlake Area of Manitoba.

Key words: Canada, Manitoba, program evaluation, regional models.

A number of agricultural resource development programs have been designed in Canada to increase agricultural productivity and improve incomes of low income farmers in rural areas. These include programs under the Agricultural and Rural Development Act, 1961 (ARDA), the Fund for Rural Economic Development, 1966 (FRED), and the Small Farm Development Program, 1972 (SFDP). The various programs have unique elements representing alternative approaches to resolving rural development problems. Establishing the effectiveness of these various programs requires innovations in evaluation models similar to the innovations Byerlee and Halter suggest are needed for agricultural sector analysis.

The purpose of this paper is to describe and demonstrate the usefulness of a dynamic regional economic model for evaluating resource development programs. The present paper deals with specific agricultural programs rather than sectorial strategies. The programs alter the resource base available to agriculture and production techniques and consequently increase agricultural output. Changes in agricultural production in turn have impacts on the level of economic activity in the region as well as other regions. For a more detailed review of the various regional development programs in Canada, see MacMillan, and MacMillan, Framingham, and Tung.

To evaluate these programs, information is needed on the economic interrelations among various sectors of agriculture and between rural and urban areas of the regional economy in order to identify the impacts of agricultural resource development programs (Heady and Sonka). The paper is organized into three sections: (*a*) structure of the dynamic simulation model, (*b*) application of the model in evaluating resource development programs, and (*c*) policy implications.

Structure of the Dynamic Simulation Model

A number of impact studies concerning the Interlake economy using a static input-output framework have been made (MacMillan and Lu 1972, 1973; MacMillan, Lu, and Framingham; Douglas and MacMillan; Molgat and MacMillan). The stability of technical relationships within and between sectors over time has been questioned on both theoretical and empirical grounds by many researchers (Theil and Tilanus, Ozaki, Sevaldson, Tung). In fact, resource development programs are directed to changing production structure. Hence, any impact study concerning resource development programs using input-output analysis needs to adjust for changes in technical coefficients and resource constraints over time.

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Under a dynamic system, first an induced consumption effect arises as the increased production yields a greater amount of regional personal income that leads to increased consumption of goods and services. Second, in order to produce additional goods generated from indirect and induced consumption effects, the producing sectors need to increase their capacity. This effect is termed the induced capacity effect.[1]

The model consists of seven submodels:[2] (*a*) final demand, (*b*) trading coefficients, (*c*) primary resources, labor and land, requirements coefficients, (*d*) capital requirements coefficients, (*e*) resource constraints, (*f*) gross output determinants, and (*g*) impact determinants. Regional economic development resulting from the forces included in the model is summarized by a set of economic indicators included in the impact determination submodel. The first set of economic indicators to be measured is realized gross output. This indicator shows the general business activity associated with and without resource development programs and is considered as an intermediate goal showing the need for resource development programs. The second set of economic indicators to be measured is directly related to the objectives of regional development programs such as area income, government revenue, and resource utilization rates. The quantitative impacts on these indicators derived from the model can be employed to assess regional development programs' achievements of specified targets in a given time period.

Final Demand Submodel

In the dynamic model, final demands are projected for two independent groups, government and other final demand sectors. A simple regression on time is employed to estimate federal and provincial government expenditure function (TFG_t):

$$TFG_t = \beta_t + \eta t. \tag{1}$$

Federal and provincial government expenditures for each target year are allocated to the seventeen producing sectors FG_{it} according to the vector of federal and provincial governments demand for regional goods and services (θ_{i0}) generated from 1968 government expenditure survey data (Hickling-Johnston Limited):

$$FG_{it} = \theta_{i0} TFG_t \text{ for } i = 1, \ldots, 17. \tag{2}$$

It is hypothesized that local government expenditures for the lth category in year t (TLG_{lt}) is determined by the community's population size in the year (TP_t) and previous local government expenditure of the lth category TLG_{t-1}:

$$TLG_{lt} = g_{lt} + \phi_{lt} TLG_{lt-1} + \rho_l TP_t. \tag{3}$$

The vector of local government demand for regional goods and services constructed for each category (T_{il}) from 1968 local government expenditure survey data is used to allocate the projected local government expenditures (LG_{it}) into the seventeen producing sectors:

$$LG_{it} = T_{il} TLG_{lt}. \tag{4}$$

The sum of LG_{it} and FG_{it} constitutes the total government expenditures on goods and services in the ith sector.

The relevant export markets in this study include the rest of Manitoba and Canada. The Manitoba growth rate of output r_i is used to project the export demand (ED_{it}) for the ith sector:

$$ED_{it} = ED_{i0}[1 + r_i]^T \text{ for } T = t - 1968 \text{ for all } i = 1, \ldots, 17. \tag{5}$$

Projection of the remaining components of final demand is also based on the Manitoba's average annual output growth rate:

$$INV_{it} = INV_{i0}[1 + r_i]^T \text{ for } T = t - 1968 \text{ for all } i = 1, \ldots, 17, \tag{6}$$

and

$$UD_{it} = UD_{i0}[1 + r_i]^T \text{ for } T = t - 1968 \text{ for all } i = 1, \ldots, 17, \tag{7}$$

where INV_{it} and UD_{it} = the net inventory

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[1] Doeksen and Schreiner state that the induced capacity effect arises during the first and second years following the initial change in investment and eventually tapers off to 0 over a period of years. However, induced consumption and capacity effects due to productivity increases resulting from development programs occur continuously over the projection period.

[2] See Tung for a more detailed description of the model and data used. Input-output coefficients (α_{ij}) show direct requirements of local input purchases (x_{ij}) and import purchases (m_{ij}) per dollar of output, i.e., $\alpha_{ij} = (x_{ij} + m_{ij})/x_{\cdot j}$, where import purchases include both intermediate and final goods. The multiplier calculated from input-output coefficients gives the increase in local area production plus imports due to an exogenous change in final demand. In the model, trading coefficients ($t_{ij} = x_{ij}/x_{\cdot j}$) are calculated to permit calculation of multiplier effects excluding imports. In the small area economy due to the magnitude of exports and imports, the underlying production theory assumptions associated with input-output coefficients are replaced with trade theory assumptions (MacMillan, Lu, and Framingham).

changes and the unallocated final demands for the ith sector in the year t, respectively.

Trading Coefficient Submodel

The nature of economies of scale for agricultural commodities in Canada can be found in the studies by Auer and by Yorgason and Spears. The generalized Cobb-Douglas type of production that permits variable returns to scale (Klein, Ozaki) is approximated in the model. Each farm size class, in terms of acreage, forms a production unit in each agricultural sector. Let FN_{jnt} be the farm numbers for the nth size class for the jth sector in the tth period. Given the assumption that the relation between imports for intermediate input and for final demand associated with each farm size class is constant, the trading coefficient for each sector in a given period (a_{ijt}) is represented by

$$(8)\quad a_{ijt} = \frac{\sum_{n=1}^{3}(AX_{jnt}FN_{jnt})}{\sum_{i=1}^{26}\sum_{n=1}^{3}(AX_{jnt}FN_{jnt})} = \frac{TX_{ijt}}{TX._{jt}}$$

for $j = 1, 2$, and $i = 1, \ldots, 26$,

where TX_{ijt} = input purchased from sector i by sector j in year t (i.e., the sum of total input i for each size class), $TX._{jt}$ = total inputs purchased by sector j in year t (i.e., the sum of total inputs of each size class, which is equal to total output from all production units), and AX_{jnt} = average per farm purchasing pattern for the nth size class in the jth agricultural sector. If changes in the distribution of farm numbers by size class and a more general form of input purchasing patterns for each size class are known, changes in trading coefficients for agricultural sectors over time can be estimated by equation (8). Mathematically, the procedures are represented by the following equations for sales to nonagricultural sectors:

$$(9)\quad TX_{ijt} = \sum_{n=1}^{3} AX_{jnt}FN_{jnt}$$

for $i = 1, 2$, and $j = 3, \ldots, 24$,

$$(10)\quad a_{ijt} = \frac{TX_{ijt}}{\sum_{i=1}^{2}TX_{ijt} + \sum_{i=3}^{26}X_{ij}}$$

for $i = 1, 2$, and $j = 3, \ldots, 17$,

and

$$(11)\quad a_{ijt} = \frac{TX_{ijt}}{TX._{jt}}$$

for $i = 1, 2$, and $j = 3, \ldots, 17$,

where TX_{ijt} = the estimated sales from the agricultural sector ($i = 1, 2$) to the jth sector in year t. A modified Markov process emphasizing migration relationships is specified by MacMillan, Tung, and Tulloch. It is used to project farm numbers by gross receipt class (FR_{ft}) using the transitional probability matrix (U'_{fm}):

$$(12)\quad FR_{ft} = U'_{fm}FR_{ft-1} \text{ for } f = 1, \ldots, 7.$$

Farm numbers are then allocated to the nth size class for the ith sector (FN_{int}):

$$(13)\quad FN_{int} = V_{ifn}FR_{ft} \text{ for } i = 1, 2,\ n = 1, 2, 3, \text{ and } f = 1, \ldots, 7,$$

where V_{ifn} = the coefficients of the number of farms for the fth gross receipt class in the nth acreage class in sector i. Given the estimate of FN_{int}, the trading coefficients are adjusted to the target years according to equations (10) and (11).

Primary Resource Coefficients Submodel

A primary resources (labor and land) requirement coefficient matrix Z_t (with elements z_{jrt}) is estimated for the initial year by the level of primary resources required by a sector to produce one unit of output. Factor productivity tends to change over time mainly due to continuous shifts in the economies of scale and continuous changes in the combination of factor inputs in production. The primary resource input requirement coefficients (z_{jrt}) are estimated as

$$(14)\quad z_{jrt} = \sum_{n=1}^{3}(fz_{jnr}FN_{jnt})$$

for $j = 1, 2$, and $r = 1, 2$,

where fz_{jnr} = the rth primary input coefficient of the nth farm size class (plant-scale) for sector j, and FN_{jnt} = farm numbers by size class. The primary input requirement coefficients (tz_{jrt}) are adjusted further by

$$(15)\quad tz_{jrt} = z_{jrt}/(1 + \Delta AP_{jr})^t$$

for $r = 1, 2$, and $j = 1, \ldots, 17$.

The growth rate of the rth primary input's

average productivity for the jth sector in year t (ΔAP_{jt}) is estimated from historical data.

Capital Coefficients Submodel

The dynamic input-output system can be extended to incorporate a replacement capital coefficient matrix as was done by Miernyk et al. To obtain the dynamic system, the final demand (FD_t) is reduced by the amount of capital investment needed to generate enough capacity to meet the realized gross output (RX_t). The explicit consideration of the capacity generating process is introduced into the input-output system by means of the B matrix for expansion of fixed capital coefficients and by the D matrix of replacement fixed capital coefficients. An element of B (b_{ij}) is defined as the purchase of expansionary capital (NI_{ij}) goods from sector i by sector j per unit increase in capacity (ΔCK_j) in sector j:

$$(16) \qquad b_{ij} = NI_{ij}/\Delta CK_j.$$

To complete the dynamic input-output system, the elements of the D matrix (d_{ij}) are defined as the purchase of replacement capital (RI_{ij}) goods from sector i by sector j in order to maintain a constant level of capacity (CK_{j0}) in sector j:

$$(17) \qquad d_{ij} = RI_{ij}/CK_{j0}.$$

The ΔCK_j and CK_{j0} must be determined a priori to estimate b_{ij} and d_{ij}, but capacity is difficult to measure since it is a vague concept. In the present study input utilization rates, the ratios of actual to potential input use, are estimated and compared. The factor that has the highest utilization rate is selected as the key factor in determining capacity for empirical estimation. The capacity for the jth sector (CK_{jt}) is obtained by

$$(18) \quad CK_{jt} = RX_{jt}/(EA_{jt}/EP_{jt}) \qquad \text{for } j = 1, \ldots, 17,$$

where RX_{jt} = the actual realized output of the jth sector in year t, and EA_{jt}/EP_{jt} = the ratio of actual to potential input use for the jth sector in year t. The increase in capacity (ΔCK_j) for sector j is then estimated by

$$(19) \quad \Delta CK_{jt} = CK_{jt} - CK_{jt-1} \qquad \text{for } j = 1, \ldots, 17.$$

For the initial year, CK_{jt-1} is estimated on the basis of 1968 utilization rates and the Manitoba growth in gross output by sector. Given the estimates of CK_{jt} and ΔCK_{jt}, equations (16) and (17) are used to determine the B and D matrices for dynamic input-output simulation.

Primary Resource Constraints Submodel

The resource constraints to be considered in the conceptual analysis should include labor, land, and capital for all sectors. The land constraint is applied only to agricultural sectors, and capital is assumed not to be a constraining factor.

The following procedures are employed to estimate future land available for agricultural production without land clearing programs. For each target year,

$$(20) \qquad LA_t = LA_{t-1} - SL_t + UL_t,$$

$$(21) \qquad SL_t = 0.1\, SL_{t-1},$$

and

$$(22) \qquad UL_t = \sigma + \pi t,$$

where LA_t = total land available for agricultural use without resource development program for year t, SL_t = amount of agricultural land converted to urban and public use in year t, and UL_t = land cleared without resource development programs, representing the amount of semiagricultural land converted to agricultural land without resource development programs. Letting UL^*_t be the increased land under the resource development programs in the tth target year, the total land available for agriculture with resource development programs (LA^*_t) becomes

$$(23) \quad LA^*_t = LA^*_{t-1} - SL_t + UL_t + UL^*_t.$$

Estimates of labor constraints for each target year are based on the demographic model of Maki, Framingham, and Sandell. The area's population size is derived from a base period to establish an estimate of a future population. The labor force is then derived from the ratio of projected population to labor force.[3]

Gross Output Determination

The basic balance equation of the dynamic input-output system is

[3] The Manitoba participation rates (labor force divided by population over 15) projected by Maki, Framingham, and Sandell increase from 0.772 for males and 0.361 for females in 1971 to 0.777 for males and 0.401 for females in 1976. The total population for the Interlake area is projected to decrease from 50,698 in 1971 to 48,311 in 1976.

$$(24)\quad FX_i - \sum_{j=1}^{17} FX_{ij} - \sum_{j=1}^{17} NI_{ij} - \sum_{j=1}^{17} RI_{ij} = FD_i - ID_i,$$

where FX_i = gross output consistent with final demand for sector i, FX_{ij} = total current input requirement by sector j purchased from sector i, NI_{ij} = fixed capital required by sector j purchased from sector i for expansion of capacity, RI_{ij} = fixed capital required by sector j purchased from sector i for replacement purposes to maintain the same level of capacity, and $FD_i - ID_i$ = the final demand with investment (ID_i) removed.

Letting A_t be the trading coefficient matrix for year t, B_t be the expansion capital coefficient matrix, and D_t be the replacement capital coefficient matrix, the dynamic input-output system in matrix form becomes

$$(25)\quad FX_t - A_tFX_t - B_t\Delta CK_t - D_tCK_t = FD_t - ID_t,$$

where ΔCK_t = change in capacity, and CK_t = capacity level at year t.

Unfortunately, the dynamic input-output system of equation (25) is not operational because ΔCK_t and CK_t are unknown. One must assume that there is a constant relation between the capacity and gross output for each sector. Thus, the ratios of capacity to gross output (FX_t) are the elements of the diagonal matrix D^* and the ratios of changes in capacity to gross output are the elements of the diagonal matrix B^*. The relations between CK_t and FX_t and ΔCK_t and FX_t are

$$(26)\quad CK_t = D^*FX_t,$$

and

$$(27)\quad \Delta CK_t = B^*FX_t.$$

The operational dynamic input-output system derived from substituting equations (26) and (27) into equation (25) becomes

$$(28)\quad FX_t - A_tFX_t - BB^*FX_t - DD^*FX_t = FD_t - ID_t.$$

Induced consumption effects through consumption-income relations stimulate the regional economy and result in an "induced accelerator" relationship. The complete dynamic system is

$$(29)\quad FX_t - A^*_tFX_t - BB^*FX_t - DD^*FX_t = FD_t,$$

where A^*_t = a matrix of trading coefficients and average propensity to consume by sector, and FD_t = final demand vector excluding household and investment sectors. Gross output by sector consistent with final demand is determined by solving

$$(30)\quad FX_t = (I - A^*_t - BB^* - DD^*)^{-1} FD_t.$$

Maximum output by sector (MX_t) consistent with resource constraints is

$$(31)\quad MX_{irt} = ZR_{rt}\frac{1}{tz_{irt}}\frac{FX_{it}}{\sum_{i=1}^{17} FX_{it}}$$

$$\text{for } i = 1, 2 \text{ for } r = 1, \text{ and } i = 1, \ldots, 17 \text{ for } r = 2,$$

where MX_{irt} = maximum output consistent with the rth primary resource constraint for the ith sector, ZR_{rt} = rth primary resource available for production, tz_{irt} = rth primary resource requirement coefficient for the ith sector in year t (see equation (15)), and $\sum_{i=1}^{17} FX_{it}$ = summation of output for the ith sector consistent with final demand obtained by solving equation (30).

Input-output analysis provides estimates of changes in output associated with a change in demand. Equation (31) can be used to calculate the maximum level of output consistent with available resources. This effectively permits output constraints based on resource scarcity, an issue neglected in standard input-output analysis. For example, the maximum livestock production (MX_{11t}) consistent with the land constraint is determined by total available agricultural land (ZR_{1t}), the land requirement per \$1,000 agricultural livestock output (tz_{11t}), and the ratio of gross output of livestock (FX_{1t}) to the total gross output of livestock and crop sectors $\left(\sum_{i=1}^{2} FX_t\right)$. The 1968 level of the requirement (Z_{iro}) for land and labor in the livestock sector are 0.05 acres and 0.44 man-years per \$1,000 output, respectively. Livestock was 71% of total agricultural output. The calculation constrains the relative use of land by livestock to be proportional to the share of agricultural output.

A similar procedure is used to estimate labor constraints for all sectors. In this case, the allocation of estimated total labor force is based on $FX_{it}/\sum_{i=1}^{17} FX_{it}$.

After the maximum output consistent with each primary resource input is determined, the maximum output of agricultural sectors (MX^*_{it}) is determined by

$$(32)\quad MX^*_{it} = \min\,[MX_{i1t}, MX_{i2t}]\ \text{for } i = 1, 2,$$

and of nonagricultural sectors is determined by

$$(33)\quad MX^*_{it} = MX_{i2t}\ \text{for } i = 3, \ldots, 17.$$

Realized gross output for each sector (RX_{it}) is then determined by comparing the estimates of gross output consistent with final demand to resource constrained output by sector:

$$(34)\qquad RX_{it} = MX^*_{it}\ \text{if } FX_{it} > MX^*_{it},$$

or

$$(35)\qquad RX_{it} = FX_{it}\ \text{if } FX_{it} < MX^*_{it}.$$

Realized gross output limited by resource constraints is referred to as supply-determined growth. On the other hand, if the realized gross output of a sector is determined by the estimates of gross output consistent with final demand then growth is demand determined. For elaboration of supply or demand-determined growth models, see Cornwall. An anonymous reviewer pointed out that, if a specific sector's output is limited (effectively) by a resource constraint, checks should be made to ensure that other "demand-determined" sector input requirements are met. In such a situation the import coefficient for the "demand-determined" sector would have to be increased, resulting in a decrease in the sector multiplier. Such a situation did not occur in the present study.

Application of the Simulation Model in Evaluating Resource Development Programs

A framework for measuring impacts of resource development programs was outlined by Barnard, MacMillan, and Maki prior to the initiation of the FRED evaluation research. FRED program managers commissioned and supported several special studies including benefit-cost analyses of manpower, drainage, and land-clearing programs. The benefit-cost analyses provided the data for sectorial allocations of program and client expenditures, the time path and magnitude of productivity benefits of the programs, and the income class designation of clients receiving benefits.

The first run of the simulation model determines the values of economic development indicators without resource development programs. The second run incorporates resource development programs into the system in determining the values of economic development indicators. In this run, the direct effects of resource development programs are incorporated in the final demand vectors. The difference between the two runs measures the combined impact of the three agricultural resources development programs on development indicators (figure 1).

A comparison of results with historical observations shows consistent projections of investment expenditures required to meet forecasted levels of output, as compared with historical observations of the capital output ratios for the agricultural sectors and factor input utilization rates due to the structural changes in the agricultural sectors, measured by an increase in the number of large farms and a decrease in the number of small farms. The forecasted factor input requirement coefficients and the trading coefficients consistent with the concept of productive capacity limitation by farm size class are very close to the observed coefficients. Economic development indicators (table 1) are simulated to permit comparison with 1976 census data when available. None of the projections exceed a deviation of 13% compared with the 1971 historical observations. The overestimation of agricultural gross output as well as farm income for 1971 may be due to the poor weather conditions in 1971.

The FRED plan allocates $85 million over the 1967–77 period to programs including manpower retraining, education, fisheries adjustment, the construction of highway and recreational facilities, drainage improvement, and land-clearing programs. Special studies of fisheries and recreation are in progress. Studies of highways, education, housing, drainage, land clearing, and manpower have been completed, but only the studies of drainage, land clearing, and farm management training have been incorporated into the dynamic simulation model.

The objectives of the drainage program ($7 million) are to increase agricultural production by increasing the quantity and quality of agricultural land. Net income associated with additional acres of crops and improved pasture existing after drainage was estimated by Norton and MacMillan (1970, 1972) to have a

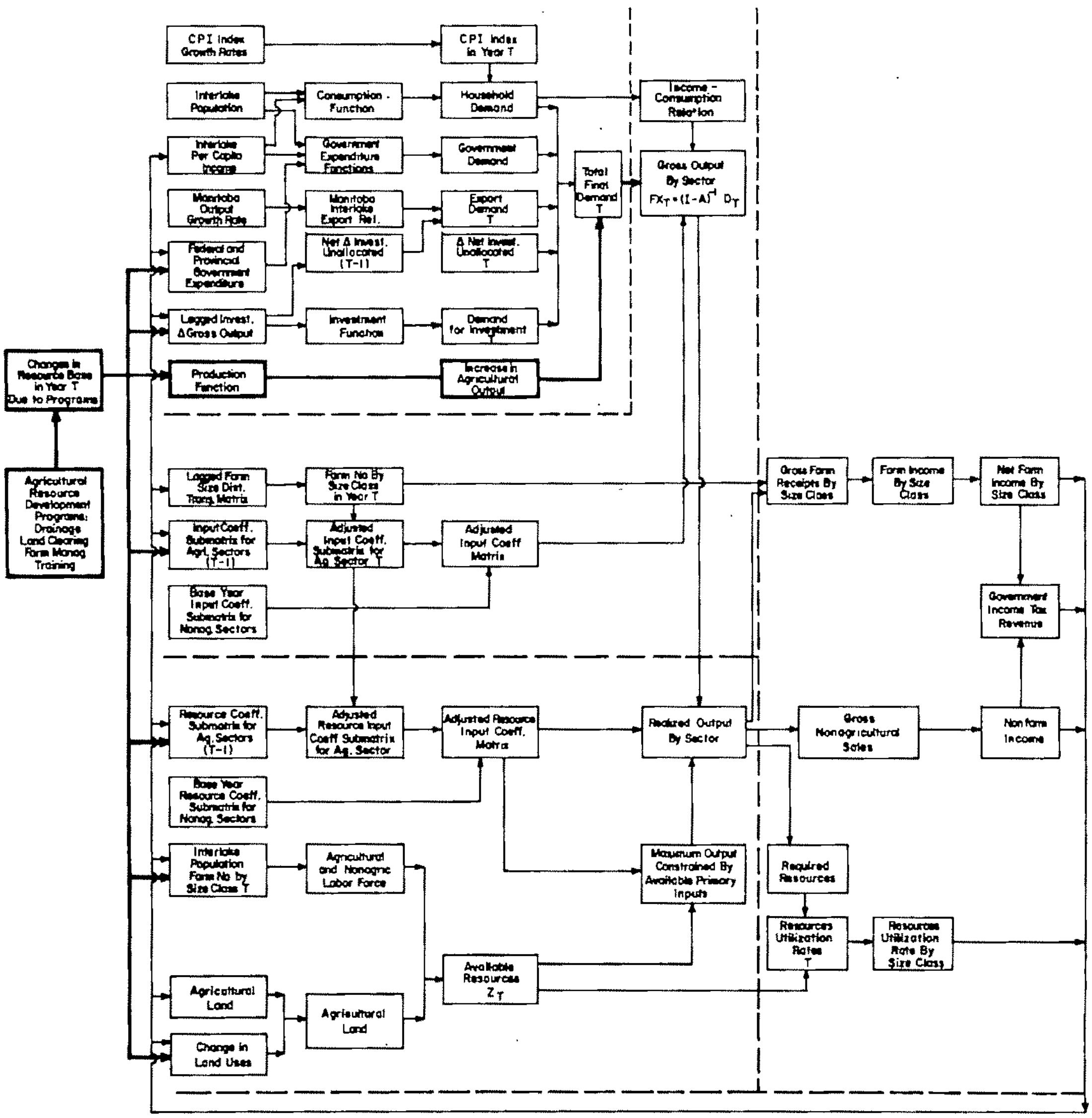

Figure 1. A diagrammatic presentation of the modified simulation procedures. The heavy solid line indicates the second step of the simulation procedures in which the effects of agricultural resource development programs are indicated in the related stages of the simulation procedure. The light solid line presents the first step of the simulation procedures.

present value of $3 million in relation to $1 million costs. The largest share of the total benefits was received by large farmers.[4]

The drainage program converts unarable land to arable land for agricultural production. Both quantity and quality of agricultural land are expected to increase through the drainage program, increasing agricultural output. The direct effects associated with the program include three aspects. First, the drainage construction expenditure can be considered as autonomous expenditures to the area economy. Thus, it will have a direct effect of increasing the area's output for the related sectors through the additional demand for goods and services resulting from drainage expenditure. When the program is terminated, the direct effect associated with drainage construction expenditure is also terminated. Second, the reclaimed land resulting from the drainage system leads to increased agricultural production

[4] The distribution of discounted drainage benefits per farm by 1969 gross receipts class estimated by Norton and MacMillan (1972, p. 51) is: $1,166 (< $2,500), $2,960 ($2,500–$4,999), $3,806 ($5,000–$9,999), and $18,194 (> $10,000). In total, 64% of the watershed income effect is estimated to be received by the 20% of the farmers in the over $10,000 receipts class in the watershed.

Table 1. Comparison of Goal Variables between Historical Observations and Model Results for the Interlake Area

Selected Economic Development Indicators	1971 Historical Observations	1971 Projection	1971 Impacts[a]	1971 Total	Difference between Historical Observations and Projection, 1971 (%)	1976 Projection	1976 Impacts[a]	1976 Total
Gross output by sector (1,000 1968 $)								
Agriculture and mining	58,430.0	50,184.0	13,119.1	63,303.1	8.3	58,840.1	18,537.1	77,377.2
Manufacturing	30,620.4	27,976.8	75.6	28,052.4	−8.4	30,733.6	98.9	30,832.5
Nonmanufacturing	—	11,030.3	889.5	11,919.8		13,750.0	602.0	14,172.0
Wholesale	—	16,986.7	2,692.8	19,758.0		20,742.1	3,583.1	24,325.2
Retail trade	44,700.0	44,102.7	3,315.4	47,418.1	6.0	49,354.8	4,007.1	53,406.5
Service	—	9,981.0	451.6	10,432.6		11,418.3	546.5	11,964.8
Total gross output	—	160,261.0	20,544.0	180,805.0		184,658.9	27,411.7	212,070.6
Employment (man-years)								
Agriculture	7,282.0	6,086.6	1,290.7	7,377.3	1.3	5,112.9	1,108.1	6,221.0
Other	9,392.0	9,642.6	232.6	9,875.2	5.1	10,261.1	221.8	10,482.9
Total	16,674.0	15,729.2	1,523.3	17,252.5	3.5	15,374.0	1,329.9	16,703.9
Land in production (1,000 acres)	1,591.2	1,607.8	57.8	1,665.6	4.7	1,868.0	114.0	1,982.0
Factor input utilization rates (%)								
Labor	96.5	87.8	—	95.9	−0.6	85.5	—	92.9
Land	90.6	92.7	—	90.3	−0.4	98.4	—	97.5
Area income (1,000 1968 $)								
Farm income	25,387.1	22,575.2	5,950.4	28,525.6	12.4	26,375.4	8,379.5	34,754.9
Nonfarm income	59,212.9	58,393.3	1,446.9	59,840.2	1.1	67,840.5	1,661.0	69,501.6
Total	84,600.0	80,968.5	7,397.4	88,365.8	4.4	94,215.9	10,040.5	104,256.5
Average farm income per farm (1968 $)	4,560.3	4,057.4	1,069.5	5,126.8	12.4	5,304.8	1,685.3	6,990.1

Note: The full detail on derivation of historical series, comparison between alternative projections, and impact results can be found in Tung. The historical observations are in many cases estimates. For example, the man-years in agriculture are based on 1968 survey results believed to be more accurate than census farm numbers that apparently undercount the number of small farms.

[a] Total impacts of drainage, land clearing, and farm management training programs.

through a reclamation effect, a flooding effect, and a productivity effect. This part of the direct effect associated with the drainage program accumulates over the implementation period since the drainage systems are designed to be completed in different time periods. Third, there is an induced farm household consumption effect associated with the drainage program through increases in net farm income and program expenditure.

The land-clearing and demonstration program is designed to stimulate expansion of cultivated acreage in order to increase agricultural production and farm income in the area. Under the FRED agreement, an incentive grant of $4 per acre is paid to farmers who clear bush on approved land. In addition to the $4 per acre grant to farmers, there are administrative expenditures including forage seed purchases, salaries paid, demonstration and rental fees, and purchases of equipment and office supplies associated with the land-clearing and demonstration program.

Additional expenditures associated with the program are incurred by farmers in contracting or purchasing equipment for clearing the land. A benefit-cost analysis from the farmer's point of view by Pareek indicated that the present value of receipts equals clearing costs after three years. Eighty percent of the farmers were cropping their cleared land three years after clearing. A large majority of participants were low income farmers.[5]

The farm management training program establishes contracts with farmers for specific five-month courses. This special program was initiated in the Interlake in 1968 and has been extended to Manitoba and other provinces in Canada. Course sessions include instructions in soil and crop management, animal husbandry, farm accounting and business techniques, and applied science and mathematics. Selection of candidates for courses is made by local committees set up by area development boards. In general, selection is based on willingness to continue farming in future, preference for younger farmers with education greater than grade 7, and presence of a farm structure with the potential for sufficient size to ensure a long-term stable income. All farmers receive training allowances from the

[5] The percentage distribution of clients clearing land by 1970 gross receipts class estimated by Pareek is: 41% (0–$5,000), 30% ($5,001–$10,000), 17% ($10,000–$15,000), and 12% (> $15,001).

Canada Department of Manpower and Immigration. A benefit-cost analysis by MacMillan, Bernat, and Flagler indicated that farm management training has a payoff to clients greater than training industry, vocational courses in community colleges, and basic training for skills development. A majority of the farm management clients were low income farmers.[6]

There are three aspects of direct effects associated with the improvement of management skills of farmers by the management training programs: direct effects associated with the actual program expenditure, direct effects associated with increases in production in the farm sectors, and direct effects associated with increased farm household consumption purchases due to increases in net farm income. Moreover, the direct effects accumulate with increases in production and in farm household consumption.

The results (table 1) show effects of the 1967–73 program expenditures of $6.8 million on drainage, $0.7 million on land clearing, and $0.9 million on farm management in 1971 and 1976. The 1971 impacts include impacts of construction expenditures in 1971. Drainage construction was completed in 1973, so construction effects do not appear in 1976 impacts. To illustrate the effects of both construction and productivity increases in agriculture over the entire ten-year plan for particular programs, the annual average impact per $1 million program expenditure is calculated (table 2). Impacts are derived from the model results relative to six economic development indicators, including gross output, household income, income per farm, employment, government revenue, and income distribution. The indicators were selected in consultation with the FRED managers. Program impacts per $1 million are useful in assessing past impacts of programs and in consultations currently being conducted to determine future allocations of rural development expenditures in Canada. Measured by the impact on increasing gross output per $1 million of government expenditure, drainage and farm management impacts are similar. Drainage has the greatest impact on household income and income per farm. Farm management has the largest impact on employment. Land clearing has the greatest impact on government revenue and low income farms.

[6] The percentage distribution of farm management clients by 1968 gross receipts class estimated from data collected by MacMillan, Bernat, and Flagler is: 17% (0–$5,000), 70% ($5,001–$10,000), and 13% (> $10,000).

Policy Implications

The results can be used by policy makers to select programs consistent with priorities. If

Table 2. Average Annual Impact of Expenditures on Resource Development Programs, Interlake Area, 1969–77

Average Impacts on Selected Economic Indicators	Average Annual Impacts per $1 Million Expenditure		
	Drainage	Land Clearing	Farm Management
Realized gross output ($1,000)[a]	2,671	686	2,592
Agriculture	1,776	419	1,675
Nonagriculture	895	268	918
Household income ($1,000)	654	164	583
Agriculture	538	127	461
Nonagriculture	117	37	122
Income per farm ($)[b]	108	25	93
Employment (1,000 man-years)	149	49	195
Agriculture	123	41	168
Nonagriculture	26	8	27
Government revenue ($1,000)[c]	66	100	64
Agriculture	51	73	49
Nonagriculture	15	27	16
Impact on low income farms (%)[d]			
Distribution of benefits (%)	36	88	87

[a] The total nine-year impact of a $1 million program expenditure is $24 million in gross output for the drainage program (2.7 × 9).

[b] Income per farm is calculated by dividing the average annual agricultural sector income by the projected 1977 number of farms (4,793).

[c] Includes property, sales, and income taxes.

[d] Percentage of drainage benefits to farms under $10,000 gross receipts calculated by Norton and MacMillan (1972), of farmers participating in the land clearing program with gross receipts under $10,000 by Pareek, and of farm management trainees with gross receipts under $10,000 by MacMillan, Bernat, and Flagler.

income distribution is a top priority, land clearing and farm management training are "best." On the other hand, if output and income creation are a top priority, drainage is "best." The results could also be used to select a mix of programs. For example, farm management programs have impacts on output and income slightly below that of drainage but have a much greater effect on low income farms. The evaluation perspective focuses on providing information needed by policy makers without placing value judgements on the relative weights among indicators.

In the evaluation of resource development programs, the assessment of future growth in the regional economy without such development programs is required for a complete evaluation. The projection of the regional development process without development programs is not only critical for measuring the impacts of development programs but it also provides insights to policy makers in formulating appropriate development programs and planning. The dynamic simulation model indicates that without development programs land may constrain livestock production after 1976. Crop production will not be land constrained because the demand for crop production is projected to increase at a rate lower than livestock. The growth in livestock production is supply determined and programs are required to expand land supply or increase the livestock production capacity of land. Growth in crop production is demand determined and will not exceed the land resource available.[7]

The model results indicate that demand and supply of labor are clearly out of balance throughout the projection period. Without the three resource development programs, the problem of the high levels of unutilized labor in the Interlake will be extremely critical with 15.5% of the labor force unutilized in 1976. A labor requirement of 15,400 man-years is projected for 1976 with 2,600 unutilized. This is due to the fact that economic development that is motivated by technological changes in agriculture will continuously decrease labor required for agricultural production. The historical and projected distribution of farm numbers by gross receipts class is given in table 3. Man-years per $1,000 gross output is projected to decline from 0.138 for livestock and 0.181 for crops in 1968 to 0.08 for crops and 0.10 for livestock in 1976. Employment in nonagricultural sectors is expected to increase but not fast enough to accommodate the outmigration of unskilled farm labor. Complementary nonagricultural manpower training and education programs are needed to provide employment for the agricultural labor force to equip them with job skills for jobs in nonagricultural sectors within or outside the Interlake area.

The introduction of resource development programs can stimulate the Interlake area's economic development measured either in terms of income generation or job creation impacts, $10 million in income and 1,300 man-years of employment by 1976 (table 1). More specifically, each program introduced to the Interlake area provides positive impacts on all selected economic development indicators. The magnitude of the impacts per dollar expenditure on development indicators is not equal. A $1 million expenditure of public investment in the farm management training program would create more job opportunities than that of the other two programs, but it does not generate as much output or household income as the drainage program. The drainage program cannot solve the income distribution problem since 64% of increased income accrues to high income classes (see table 2).

The impacts of each resource development program on the selected economic development indicators are different from one time period to another. Detailed special studies of

Table 3. Historical and Projected Farm Numbers by Receipts Class

Gross Receipts Class	Historical 1971[a]	Projected 1976[b]
	Farm Nos.	
< $2,500	2,169	1,442
$2,500–$4,999	1,129	845
$5,000–$9,999	970	857
$10,000–$14,999	460	491
$15,000–$24,999	428	554
> $25,000	399	783
Total	5,564	4,972

[a] From Statistics Canada (1973).
[b] Projected using the model estimated by MacMillan, Tung, and Tulloch.

[7] Land cleared under the program over the period 1969–73 totaled 126,000 acres. Without the land-clearing program, 2 million acres were estimated to be available for agricultural production in 1976, which is equal to the land requirements estimated from the model. Land requirements are estimated from the model at 2.3 million acres in 1985, a short fall of 0.3 million acres. The annual growth rate projected for livestock output is 5.15% and for crops 3.45%, indicating the short fall is primarily due to livestock demand.

particular programs are required to provide productivity measures including benefit-cost ratios as well as link program expenditures to the regional economy. The simulation model highlights the accumulation of "pump priming" and productivity effects in contrast to the present value results of benefit-cost analysis.

Governments could be more effective in their pursuit of development targets by making objectives more specific in terms of the selected economic development indicators and analyzing the economic and structural changes caused by particular programs on an annual basis. Infrastructure expenditures in early years of a plan can provide jobs immediately in contrast to the several years required to generate jobs by increasing management skills of farmers.

A dynamic simulation model and data used in the study have several limitations including the scarcity of available data.[8] A serious limitation in the present model is the omission of adjustments for technological changes occurring within nonagricultural sectors. Capital constraints are not included in the model due to the complexity of capital flows among regions.

The omission of price changes in the model is a major limitation. The constant price ratio assumption used in the present model eliminates the substitution effect caused by relative price changes. In addition, the omission of price changes over time in the study prevents an analysis of the erosion in development impacts due to the decrease in purchasing power of program expenditures in later years of the plan due to inflation (see Johansen). The model cannot handle weather conditions affecting the agricultural input-output relations, and projections over the long term will show short-term variations due to weather fluctuations.

In summary, notwithstanding its limitations the dynamic simulation model described and applied in this study can be used to trace out the principal forces determining the pattern of regional development and in measuring the impacts of resource development programs on a regional economy.

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[8] The estimates for the drainage by Norton and MacMillan, land clearing by Pareek, and farm management training impacts by MacMillan, Bernat, and Flagler were based on detailed sample surveys of fifty-one, ninety, and twenty-six farmers, respectively, and allocations to input-output sectors of the FRED budget were made in consultation with FRED administrators. Data on local government expenditures by sector were obtained by a detailed survey of local government expenditures by the Department of Agricultural Economics, University of Manitoba. The sectorial allocation of provincial and federal government expenditures was estimated from the business questionnaire results used in the estimation of the 1968 Interlake area transactions matrix. Allocations to particular expenditure functions were based on a 1968 survey of provincial and federal government expenditures conducted in 1969 by Hickling-Johnston Associates for the Manitoba Planning and Priorities Secretariat. The statistical properties of the household and business data used in constructing the 1968 transactions table are detailed in MacMillan, Lu, and Framingham. Investment rates were estimated from the Manitoba 1950–72 series obtained from Statistics Canada. Gross output rates of change were estimated from Manitoba Department of Finance data and the Commission on Targets for Economic Development. Agricultural and population data series were obtained from the Census of Canada (Statistics Canada 1950–72, 1973) and the Manitoba Department of Agriculture publications (1960–72).

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Implications of Public School Finance Reform with Local Control

Fred C. White and Bill R. Miller

The nation's present interest in school finance reform concerns elimination of inequities in financing and improvement in the delivery of educational services. This paper examines one of the most popular school finance reform proposals that would allow the local school district to select an appropriate tax effort without directly linking quality of education to the district's wealth. Implementation of this reform proposal would result in a slight redistribution of income to poorer districts but would result in further inequities in quality of educational services.

Key words: school finance, taxation.

Local control of public schools has always been an important part of the educational system in the United States. With the exception of meeting some minimum requirements, local school districts have a great deal of flexibility in establishing their financial commitment. Differences in educational programs among school districts can, therefore, be attributed primarily to differences in fiscal capacity and commitment of residents to the support of education.

A major criticism of the present system of public school finance concerns the wide disparities with respect to tax burdens. There is a divergence among school districts with respect to tax rates and the level of expenditures per student generated by these tax rates. Wealth has been identified by various state courts as causing this problem because it was not distributed equally (Advisory Commission on Intergovernmental Relations 1973). A variety of financing plans for education are acceptable under the court rulings so long as quality of the educational program is not subject to the school district's wealth.

Selection of the appropriate instrument for public school finance reform requires clarification of educational goals. Reform proposals that appear widely acceptable maintain local control of tax rates without subjecting expenditure levels to local school district wealth. An alternative that meets these criteria—power equalization—has been proposed by Coons, Clune, and Sugarman. Under this plan, state aid is used so that at any level of tax effort every school district would receive the same level of revenue per student. If a district's tax base produces less revenue at a given rate than the permitted revenue level, the difference would be provided by the state general fund. Any excess over permitted levels would be contributed to this fund. Local school districts would establish their own tax rates for education, with expenditure levels determined by the selected tax rate and state average wealth.

Each district would select that tax rate appropriate to voter preferences within the district. This selection would also take into consideration factors associated with production including economies of scale in producing education and price of factor inputs. Thus the problem can be formulated in terms of supply and demand for education. However, previous discussions of power equalization have considered implications of tax reform while abstracting from relevant supply-demand considerations (Coons, Clune, and Sugarman; Treacy and Frueh; Weiss; Stubblebine and Teeples; Oakland). An exception to this statement is the work by Feldstein, who measured wealth neutrality by the elasticity of local school spending with respect to local per pupil wealth. To a large extent, power equalization must be evaluated on the basis of local communities' responses to the incentives it offers, which requires a knowledge of the pa-

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rameters of communities' supply and demand functions for education.

Objectives

This article explores public school finance reform in Georgia. It first develops a method to quantify equilibrium levels of public school finance variables such as total current school expenditure minus transportation costs, state and federal aid to education, and supply and demand of local expenditures. Then the theoretical concept of supply and demand is structured as a set of simultaneous equations, which is estimated from cross-sectional data describing public school expenditures in Georgia counties. Finally, the estimated supply and demand relationships are applied to identify equilibrium levels of spending in local districts after removing inequalities due to differences in tax base.

Analytical Framework

In this research we specify public school services as a recognizable, although not measurable, output to the taxpayer but persist as others have in maintaining that the theory of supply and demand does apply. This approach follows Buchanan's theoretical analysis of supply and demand for public goods, as well as the empirical analyses of Barlow, McMahon, Ohls and Wales, and Borcherding and Deacon. Basic economic theory is shown to prevail in these empirical studies and others despite the explicit recognition that price and output of public services are not objectively measurable.

A principal difficulty in observing output quantities suitable for analysis is that the theory of supply and demand is traditionally discussed in terms of homogeneous units. Such units are clearly not produced by the school system. Students are part of the system input and their acquired skills and achievements are an obvious output, but the educational level of every student is different. A detailed discussion of the analytical framework explaining supply and demand for educational services follows.

Supply and Demand Variables

From a theoretical point of view, we use the commonly held assumption that a quantity index of educational service (Q) as demanded by the taxpayer is a function of prices of competitive goods and services, a price index of educational service (P), and the taxpayer's income. Similarly, Q is a function of the efficiency with which our schools are run, as this affects the cost of education, i.e., quantity demanded may not be supplied if costs are too high. There is a measurable total cost of obtaining these educational services, although neither the service nor its unit of quantity and price can be uniquely defined. Furthermore, from an empirical point of view there is not much hope that an empirically useful index of quantity or price will ever be defined. Nevertheless, the hypothesis that there are aggregate ratios of tax effort and educational cost to consumer income that contain within them the elemental forces of demand and supply is maintained. In this respect, we follow McMahon in his recent study of the expenditure-income ratio.

Perhaps importantly for economic analysis, measurable and observable costs of producing educational services are subject to modification not only by consumer behavior to tax structure on the demand side but also by changing costs and productivity on the supply side of the market. This interplay of market forces is observed as the local taxpayer pays the cost of consuming educational services through payment of taxes.

Any theory of demand for educational services that hopes to specify the behavior of consumers must explain the taxpayers' recognition of the interaction between expenditures and taxes. In this process the taxpaying consumer's economic behavior with respect to the case of consuming educational services is observed. Barlow is most explicit on this point. "Of all the major public expenditures in the United States, the expenditures of local public schools are perhaps the most responsive to the preferences of individual citizens" (p. 1028). Further evidence of the strength of this point of view is found in Bowen and Downs.

Simultaneous with the taxpayer's establishing and paying taxes, conditions are arising that seem to dictate the level of costs required for a given level of services. This is no different from the forces observed in any market. The supply of educational services, like the supply of any good, is related to factors affecting total costs: scale of plant, input mix within the school, and input prices. Borcherding and Deacon, for example, develop an explicit production function for education. Unlike other

markets, however, knowledge of the cost function is not sufficient to specify supply at the local level. Local costs of education and level of educational output may also vary among school systems because of differences in outside effort from state and federal sources. Thus, determination of local level of education is confounded, not only by the lack of measurable units of service, but also because the equilibrium level of local taxing must be found with respect to the level of local costs and outside government transfers. Inclusion of outside effort in the equilibrium process is consistent with common observation of the school economy, which demonstrates that the output of public goods would in general be too small without evolution of government systems to correct deficiencies. McMahon has also emphasized the exogenous character of outside aid. Thus, it appears that the equilibrium level of local tax contribution towards total costs of educational services is simultaneously determined by consumer demand for services, educational supply costs, and outside effort. This structure of relationships implies that local cost conditions cannot be brought into stable equilibrium with what local taxpayers are willing to pay until the exogenous level of outside effort is set by current policy of either simple grants or complex formula.[1] "The basic decision is the decision about how much to tax, which is constrained to a choice between taxing and borrowing, given state and federal aids" (McMahon, p. 245). We demonstrate a simultaneous equation model of these structural relationships below.

Operational Model

Specification of supply and demand for education requires at least two definitions. One, there must be an observable value that is subject to modification by consumer behavior in response to a measure of change in educational services. The hypothesis that property tax effort in Georgia has been responsive to the observed level of educational services is tested, although this effect is not as direct as previous studies have assumed. In brief, tax effort is a function of what taxpayers continually perceive as output from the school system. What is perceived as output and the quality of this output is then specified to be a function of the educational services provided by the school system. The second requirement is that the change in educational services must be an observable and measurable index. As we have already argued and as a number of studies suggest, total school expenditure meets this criteria; with modifications for achievement and efficiency of inputs, we use it as such in this study (Cohn, Riew).

A four-equation model is specified in which tax effort, achievement, total expenditures, and local expenditures are the four endogenous variables. The simplified structural form of the endogenous relationships appear as follows:

(1) Demand or Effort:
$$LTE = F(ACH;\ X_1 - X_5),$$

(2) Quality of Output:
$$ACH = F(EXP;\ X_6 - X_8),$$

(3) Cost of Output:
$$EXP = F(ACH;\ X_9 - X_{13}),$$

and

(4) Identity: $EXP = LX + OT$,

where LTE = local school tax effort for current expenditures per dollar of personal income, ACH = county average achievement score, EXP = total current expenditure per average daily attendance (ADA), LX = current expenditures per ADA financed from local sources, OT = county current expenditure per ADA funded from state and federal sources, and X_j = exogenous shifters of the functional relationships that will be described in detail later. This is a consistent model with regards to the endogenous relationships of stochastic variables. The following sections discuss these relationships in detail.

Demand as Tax Effort

Local tax effort reflects demand for services, including the willingness to supply the funds. The Advisory Commission on Intergovernmental Relations suggests that tax effort is effectively measured by the ratio of tax revenue to personal income (1962, 1973). Since school tax revenues are the observable local contribution to public education, we test the hypothesis that consumers as taxpayers are willing to increase local current expenditures per dollar of income whenever they observe increasing student achievement, other things being equal. Thus, demand expressed

[1] Under some aid formulas, the level of outside aid is not entirely exogenous but affected by the district's decisions on type of programs and financing.

as local tax effort is defined to be $LTE = (LC/CY)(100)$, where LC = local contributions for current expenditures (excluding transportation), and CY = county income. Thus, the numerator is total local contribution of current school expenditures, and the denominator is the county's total personal income.

Quality of Output

Kiesling has pointed out that it is a dangerous practice to use expenditure data as an index of change in educational services without an allowance for differences in quality. Kiesling also concludes that, "given the well-known problems in measuring public service outputs, it is surprising that test scores have not been more widely used by economists in education research" (p. 356). Test scores, or student achievement scores, are among the immediately recognizable results that taxpayers observe from the educational system. Even when test scores are not known, they are closely related to those things that taxpayers do observe, such as high school dropout rates, the number of students attending college, the initial job success, and the success in post-secondary schooling. Thus, in this research it is assumed that tax effort by taxpayers is jointly determined with the observed level of quality as measured by achievement. Other measures of quality are no doubt available, but achievement scores offer the advantage of being widely available and comparable to some degree. We hypothesize that local tax effort (LTE) will rise as achievement levels rise and that there is an endogenous relationship between achievement and the cost of educational services.

Cost of Output

Although previous research results aimed at identifying the relationship between student achievement and expenditures have been inconclusive (Coleman et al., Flanagan et al., Jencks et al.), the present analysis will explore the possibility of such a relationship. The logical assumption is, with other things being equal, higher quality output has a higher unit cost. Our estimates of total current expenditures per ADA are thus related to quality by including achievement in the equation for EXP; simultaneously, EXP is expected to affect achievement. Other important determinants of cost are then added to the equation as exogenous variables as an attempt to adjust for their effect and thereby isolate the expenditure-quality relationship.

Identity

The statistical model is closed by specifying that total expenditure per student (EXP) minus local expenditure per student (LX) equals outside effort per student (OT). Outside aid is determined by a formula (which may consider differences in cost as well as ability to pay) making the amount coming to a district exogenous to the district. After that, the district is left to itself to make LTE consistent with LX.

Exogenous Variables

The statistical model allows the number of students measured as ADA to be an exogenous variable. One of the causes of imbalance in local school system financing is economies and diseconomies of size in student enrollment that are exogenous or beyond control of the system. The number of students has a significant effect on educational costs per student. Several researchers including Hirsch, Schmandt and Stephens, Riew, Cohn, and Hanson have examined economies of size in public education. Hanson reported that, in general, school districts exhibited economies of size up to about 50,000 pupils in ADA (p. 92). Schmandt and Stephens thought schooling quality was closely related to expenditures. They reported that school district operations exhibited economies of size in providing a given quality of education but larger per capita expenditures were usually associated with larger populations.

In addition to differing levels of ADA per local school system, school systems also exhibit differences in the pupil-teacher ratio (PTR), average salaries paid to teachers ($AVSAL$) and average nonteacher instructional expenditures per classroom (INS). Increases in PTR tend to decrease expenditures, while increases in salaries and classroom expenses raise expenditures.

Exogenous influences also affect the demand equations of the system. Achievement is widely held to be greatly influenced by the socioeconomic background of the student (Coleman et al., Flanagan et al.). In this study, variables affecting achievement were

considered to be the county average mean years of schooling (*MYS*), percentage of the county's black population (*BLK*), and average student IQ scores in the county. A dummy variable (*LIQ*) was used to reflect differences in average IQ scores. The value of *LIQ* was 1 for those counties with average eighth grade IQ below 80 (approximately 4% of all counties) and 0 otherwise.

With respect to local effort, *LTE* was hypothesized to change with wealth as measured by the county property tax digest (*DIGEST*), to vary with dependency rates as measured by average daily attendance per capita (*ADA/POP*), to change as outside federal and state help per ADA (*OT*) increased or decreased, to change with the county's per capita income (*PCI*), and to vary among urban and rural counties as measured by population per county (*POP*).

Estimation Results

Secondary data from various agencies, particularly the Georgia Department of Education (1971, 1972), were used to estimate the simultaneous equations model.[2] Counties were used as the unit of analysis rather than school districts in order to better identify community characteristics. However, this simplification should not abstract from the school district decision-making process, as 83% of Georgia counties have county-wide school districts. Equations of the model were estimated by three-stage least squares; the coefficients and Student's t-values are shown below:

$$(5)\quad LTE = \underset{}{-0.316} + \underset{(1.99)}{0.026\,ACH} + \underset{(5.18)}{0.030\,DIGEST} + \underset{(4.49)}{0.108\,ADA/POP} + \underset{(5.76)}{0.622\,POP} - \underset{(-12.30)}{1.161\,PCI} - \underset{(-3.96)}{0.003\,OT},$$

$$(6)\quad ACH = 58.32 + \underset{(2.87)}{0.008\,EXP} + \underset{(8.04)}{1.418\,MYS} - \underset{(-19.69)}{0.207\,BLK} - \underset{(-5.51)}{6.548\,LIQ},$$

and

$$(7)\quad EXP = 549.2 + \underset{(2.59)}{1.272\,ACH} - \underset{(-3.94)}{3.028\,ADA} + \underset{(4.70)}{0.082\,(ADA)^2} - \underset{(-21.80)}{27.73\,PTR} + \underset{(12.08)}{51.81\,AVSAL} + \underset{(21.54)}{0.061\,INS}.$$

Implications inferred from the estimated signs of the equation coefficients are discussed below.

The reduced form equation for local tax effort is obtained by substituting the equation explaining achievement (*ACH*)—equation (6)—into the equation describing aggregate county demand (*LTE*)—equation (5). Since achievement is increasing with expenditure and aggregate demand (*LTE*) is increasing with achievement, the reduced form equation shows *LTE* to be a slightly upward sloping curve with regards to expenditures. Aggregate demand then shifts up or increases with increases in mean years of schooling in the population (*MYS*), decreases if the county has low average intelligence scores (*LIQ*), increases as wealth measured by property tax digest (*DIGEST*) increases, and shifts up with an increase in dependency rates (*ADA/POP*). The study showed significantly through equation (5) that local demand decreased as state and federal aid increased (*OT*). Thus, in some cases while it appears desirable to increase the level of outside help to bring supply-demand relationships into equilibrium, this can only be done at the sacrifice of local effort. The LTE ratio decreases as incomes increase.

Signs of the variables in equation (7) indicate that costs increase as average salaries increase, as average instructional expenditures per classroom increase, and as the average pupil-teacher ratio decreases. Expenditures also increase with achievement indicating that school administrators tend to spend more where results have been good. As *ADA* increases from the lowest levels, expenditures fall until the minimum cost of *EXP* with respect to *ADA* is reached. Thereafter, increases in *ADA* will cause expenditures to rise.

Power Equalization

This section applies the supply and demand relationships estimated above in order to

[2] Specific data sources include U.S. Department of Commerce for population characteristics, Georgia Department of Revenue for tax digest, and Georgia Department of Education (1971, 1972) for school expenditures and achievement scores.

quantify the impact of power equalization.[3] We will direct our attention to a form of power equalization that links state aid to the tax rate chosen by the community. This aid program would equalize the cost of any expenditure level for the local district. The level of spending for each district is determined by equilibrium supply-demand considerations.

Under power equalization, the level of state aid received by a locality will depend on the ratio of its wealth to that of some other key district as specified by the state. Selection of the key district is important in determining the appropriate level of state aid, as shown by the formula for determining the state's contribution to educational expenditures: state aid ratio $= 1 - \frac{\text{local wealth}}{\text{key district wealth}}$. For example, if a school district's wealth is 10% of the key district's wealth, the state will fund 90% of any total expenditure level selected by the district.

Using an average district as the key tends to redistribute wealth. When equalizing a low wealth district to an above average district, the state adds wealth to the average local wealth (Coons, Clune, and Sugarman). The particular power equalization program used in this analysis is one in which the aggregate level of state funding was held constant at its actual level. Although state aid for a specific district would be dependent on supply-demand considerations, federal aid was assumed to remain at its actual level for the district. Since the state accounted for 49.1% of total educational funding, the wealth level selected for the key district was above average in order to maintain aggregate state funding.[4]

Simulation Procedure

From equation (5), wealth as measured by tax digest per ADA was identified as an important demand shifter. Under power equalization, the effective level of wealth used in estimating each county's demand for educational services would be the same. Even so, demand for education would still be variable among counties as would their equilibrium expenditures on education.

Before introducing the power equalization option, it is important to examine the process by which equilibrium in the present model is reached. From equation (4), equilibrium is defined as the source of funds—local contributions and outside aid—being equal to the cost of education. Power equalization will shift the local tax effort or demand curve by changing the district's effective level of wealth. The new level of demand will intersect with costs to determine an equilibrium expenditure and hence the level of available state aid. For a given level of outside help, state aid, and county income, a county must adjust local effort until the cost of education is just equal to all available funds. This adjustment process would be necessary if factors affecting the cost of education, such as teacher salaries, nonteacher classroom expenditures, and pupil-teacher ratios, were inflexible. In this case, each district would be forced to raise local taxes until the cost of education would be covered. On the other hand, if these expenditures could be modified, equilibrium would be reached by increasing or decreasing these expenditures until local contributions and all outside aid were just equal to education expenditures. Both adjustment processes will be examined through an iterative procedure, programmed to adjust either the level of total expenditures or local effort and corresponding outside aid, while satisfying the estimated model.

Simulation Results

Actual expenditures (current operating expenditures minus transportation costs) averaged \$588 per ADA with a standard deviation of \$107. With an adjustment framework in which total expenditures would be adjusted so as to equate the sum of local contributions and state aid with total expenditures, average expenditures would be reduced 9%. Since this adjustment process would more effectively reflect differences in local demand for education, the variability in expenditures among districts would increase. The standard deviation of expenditures would be \$139. If expenditure components were taken as given and the school district had to increase local taxes to make up the difference between total cost and

[3] There may be some question as to the reliability of estimating school district response to power equalization that may collect more taxes from some districts than they spend on schools when based on data where all have some state aid. However, extrapolation from available data should certainly be considered as an important step in evaluating this policy alternative.

[4] County digests ranged from a low of \$22,000 per ADA to a high of \$92,000 per ADA. Assuming that schooling expenditures would be inflexible downward and that the state wished to maintain its present level of school funding, the digest selected as the key district would be \$65,000 per ADA.

outside aid, average expenditures would be 6% higher than actual expenditures, with a standard deviation of $110. In both cases, state aid is determined by the district's wealth and its local effort. Since it was assumed that aggregate outside aid would be held constant, differences in the average expenditure would also reflect differences in local contributions. Although these state averages are informative, it is also important to examine the impact of power equalization on districts with different characteristics.

Equilibrium tax efforts under the power equalization program were compared to actual tax efforts on a county by county basis. Results are summarized in table 1 by district wealth and in table 2 by population size. For both characteristics, counties were divided into three groups with an equal number of counties in each group. Local expenditures and state and federal expenditures reported in these tables reflect the portion of total expenditures that are financed by local sources and state and federal sources, respectively.

Since the state will share in the cost of improving the quality of education, poorer districts have an incentive to increase local effort under power equalization. The one-third poorest counties in terms of digest per ADA have the highest expenditure per ADA under power equalization relative to actual expenditures (table 1). However, the absolute level of expenditures is higher in the wealthier counties, which reflects greater demand for educational services in these counties. Power equalization results in some income redistribution. The one-third poorest counties would receive an increase in aid of $30 to $50 per ADA compared to a similar reduction in the one-third wealthiest counties.

The level of spending selected by individual counties would depend on the flexibility of

Table 1. Educational Expenditures for Georgia Counties Categorized by County Wealth, under Alternative Adjustment Processes

	Adjust Total Expenditures			Adjust Local Contributions		
	Digest per ADA[a]			Digest per ADA[a]		
	Less than 33,000	33,000–38,000	Greater than 38,000	Less than 33,000	33,000–38,000	Greater than 38,000
	$ per ADA					
Local expenditures						
Actual						
Average	130	169	323	130	169	323
Standard deviation	(39)	(50)	(140)	(39)	(50)	(140)
Equilibrium						
Average	69	95	286	90	137	389
Standard deviation	(14)	(19)	(163)	(16)	(24)	(184)
Outside aid						
Actual						
Average	365	382	341	365	382	341
Standard deviation	(52)	(53)	(49)	(52)	(53)	(49)
Equilibrium						
Average	425	379	315	432	416	281
Standard deviation	(48)	(52)	(49)	(44)	(44)	(81)
Total expenditures						
Actual						
Average	515	550	664	515	550	664
Standard deviation	(42)	(61)	(117)	(42)	(61)	(117)
Equilibrium						
Average	494	474	601	524	553	670
Standard deviation	(50)	(66)	(184)	(39)	(57)	(125)
	ADA					
Total number of students	262,900	329,220	414,239	262,900	329,220	414,239

[a] Counties were divided into three groups with an equal number of counties in each group.

educational expenditures. If expenditures were flexible downward, average expenditures would be reduced in all three wealth categories (table 1). However, if these expenditures were rigid downward, equilibrium expenditures would be slightly above actual levels, reflecting that a few districts would choose higher expenditure levels while none would be able to lower their expenditures.

There is a direct relationship between total expenditures and county population (table 2). This relationship reflects the fact that rural residents have a lower effective demand for education. However, the cost of providing education is also lower in rural areas as reflected by equilibrium expenditures in the case of inflexible expenditures (table 2). Power equalization would result in a redistribution of aid that would favor urban counties. Even in the case in which outside aid was higher for rural counties, it was still lower than actual aid (table 2).

Further Implications

Major advantages of power equalization include local control of educational expenditures and uniform burden of financing additional educational services for taxpayers in similar situations. Decision making with respect to expenditure levels is kept on the local district level. Rather than forcing all districts to accept the same level of expenditures, each local district can select an expenditure level that would be appropriate for its needs and tastes. However, expenditure levels would not be based on the local school district's wealth. Since a given tax effort—taxes per dollar of wealth—would support the same level of educational services, disparities in educational expenditures would not be wealth induced. Thus, an individual's tax burden would be based on the quality of education that his community desired and not the community's wealth.

Table 2. Educational Expenditures for Georgia Counties Categorized by County Population, under Alternative Adjustment Processes

	Adjust Total Expenditures			Adjust Local Contributions		
	County Population*			County Population*		
	Less than 9,000	9,000–18,000	Greater than 18,000	Less than 9,000	9,000–18,000	Greater than 18,000
	$ per ADA					
Local expenditures						
Actual						
Average	120	121	252	120	121	252
Standard deviation	(46)	(31)	(131)	(46)	(31)	(131)
Equilibrium						
Average	91	83	190	185	137	252
Standard deviation	(45)	(25)	(157)	(167)	(62)	(189)
Outside aid						
Actual						
Average	439	407	350	439	407	350
Standard deviation	(66)	(53)	(46)	(66)	(53)	(46)
Equilibrium						
Average	334	350	370	375	391	358
Standard deviation	(96)	(68)	(62)	(164)	(67)	(87)
Total expenditures						
Actual						
Average	560	528	602	560	528	602
Standard deviation	(70)	(50)	(114)	(70)	(50)	(114)
Equilibrium						
Average	426	433	561	561	529	609
Standard deviation	(58)	(51)	(143)	(58)	(49)	(117)
	ADA					
Total number of students	78,577	150,467	777,315	78,577	150,467	777,315

* Counties were divided into three groups with an equal number of counties in each group.

We have utilized two adjustment frameworks in analyzing the power equalization program. Deciding which framework is most appropriate hinges on the flexibility in educational expenditures. Such expenditures as teacher salaries and nonteacher classroom expenditures are more likely to be rigid downward in the short run. Only in the long run would district demand play a role in retarding increases in these expenditures so that expenditures would be brought in line with desired levels of educational services.

To this point we have said little about the limitations of power equalization. However, the approach does have some shortcomings: (*a*) the level of educational expenditures may vary excessively, (*b*) there may be a tendency for parents to switch their children to private schools, (*c*) it may be politically infeasible to take financial resources away from education in wealthier districts, and (*d*) public school finance will still be dependent primarily on the property tax.

Disparities in educational expenditures persist with power equalization; the data for Georgia revealed that power equalization would not reduce variability in educational expenditures. In the short run, power equalization would have little impact on variability of expenditures, but in the long run variability would increase, reflecting differences in local districts' demand for educational services. Disparities would also reflect differences in scale and factor prices rather than simply differences in ability to support education.

Power equalization takes resources away from education in wealthy districts. Thus, wealthy parents may choose to place their children in private schools rather than call for greater support of public education within the local district. This conclusion assumes that wealthy property owners are primarily responsible for determining the level of educational support. Since this may or may not be true, further research is required before this criticism can be properly evaluated.

Present equalization programs for education achieve only a modest redistribution of resources to poorer districts. Each local district's share of the minimum foundation program is inversely related to its wealth. However, most programs include a minimum guarantee that ensures that even wealthy districts will receive substantial state support. All districts are eligible for additional state funds through various provisions of the aid programs. As an example of the final distribution of state aid funds, actual state aid per student in Georgia ranged from \$197 to \$488, with some wealthy districts receiving above average levels. Provisions that effectively restrict the present program's ability to redistribute income were included to gain acceptance for the program from wealthy districts. Since a power equalization program has no such provisions, widespread political acceptance may be more difficult to achieve.

The property tax is continually under criticism: as an efficiency destroying excise tax placed on housing, as a burden on the elderly, and as the most regressive tax in the present public finance system. Despite all of these criticisms, we have not seen fit to substantially replace the property tax. Indeed, recent evidence questions many of these criticisms (Lindholm). Thus, the task remains to modify the property tax to overcome its major weaknesses. Power equalization is one such reform that would improve the property tax's use in financing public services.

Summary and Conclusions

Interdistrict inequity is one of the most pressing problems in school finance. Although landmark court decisions call for reform in school finance, states still have a great deal of flexibility in determining how equity problems will be solved. This paper has analyzed implications of one of the most popular reform proposals—power equalization. Implementation of power equalization in Georgia would result in a relative increase in expenditures in districts with lower levels of wealth, as well as a reduction in local effort for these districts. Rural counties, on the average, would lose state aid if the program was implemented.

Power equalization offers individual districts greater financial incentive and control. At the same time educational opportunities are dependent upon the local district's effort to support education and not on its wealth. Rather than using an arbitrary foundation level based on state-designated needs, each district can determine its own educational program based on such factors as special needs, tastes, scale considerations, and factor prices.

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Optimizing Subindustry Marketing Organizations: A Network Analysis Approach

Stephen W. Fuller, Paul Randolph, and Darwin Klingman

A technique for solving large-scale mixed-integer plant-location problems is developed and utilized. The plant-location problem is formulated as a minimum-cost-flow network problem and solved with a special purpose network code in conjunction with implicit enumeration. Implicit enumeration reduces the number of plant combinations that need to be examined. The technique was applied to resolve a cotton-ginning subindustry's least-cost organizational adjustment to exogenous factors and involved consideration of short-run plant costs that were piecewise linear with fixed charges, two-levels of variable labor cost, storage costs, and assembly costs.

Key words: cotton gins, mixed-integer location problems, plant location.

The problem of estimating efficient market areas or marketing subindustry organization has received extensive treatment in the *Journal*. Early models developed and applied by French, Henry and Seagraves, Olson, and Williamson treated space as continuous and assumed that a region had uniform average density of supply or demand. The solution specified the most efficient plant size and corresponding market area dimensions. A later model development by Stollsteimer was capable of including preselected potential plant locations and discrete supply or demand locations. The solution communicated least-cost number, size, and location of marketing facilities. Recent extensions of the basic Stollsteimer model by Polopolus, Chern and Polopolus, Ladd and Halvorson, and Warrack and Fletcher have enabled the applied researcher to incorporate additional realism, test sensitivity of solution, and increase size of plant-location problems. King and Logan applied a transshipment model to a plant-location problem where materials may move from a supply point through another intermediate supply point and on to the demand point and/or through an intermediate demand point. Hurt and Tramel and Leath and Martin have extended this model to incorporate additional realism. Toft, Cassidy, and McCarthy have developed a sensitivity test to determine the stability of solutions obtained with the transshipment model. To accommodate those situations in which nonlinear long-run total processing costs exist, Kloth and Blakely employed separable programming, while Candler, Snyder, and Faught used concave programming.

This article reports on a plant-location model developed to determine a processing industry's least-cost organizational adjustment to a region's decreased raw product output and new storage technology. Existing plant-location solution procedures were unable to incorporate necessary realism and, if modified to do so, generally required extensive computer time to obtain a solution. To overcome these limitations, a locational problem was formulated as a network problem and solved with the use of a special purpose primal simplex code in combination with implicit enumeration. This solution procedure should be of general interest to applied economists involved in locational analysis.

The location problem focuses on the trade-offs between plant numbers or cost and transportation cost, storage cost, and payment of

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overtime plant-labor costs. The objective was to specify which processing facilities to activate and the spatial and temporal flow of raw product to the activated plants in order to minimize the total cost of assembly, storage, and processing.

Problem Situation

Cotton production in several southwestern irrigated valleys has decreased by 50% during the past decade, while regional processing (ginning) capacity has remained relatively unchanged. Furthermore, recent innovations in seed cotton storage permit extension of assembly and processing activities beyond the current harvest period, thus decreasing an area's required processing capacity.[1] Because of the nature of variable plant costs and the feasibility of seed cotton storage, it was hypothesized that total system costs could be decreased from current levels by reducing the number of operating plants.

Each plant in this study has a unique, piecewise linear variable cost function with a positive intercept (figure 1). The positive intercept value represents a one-time annual fixed charge for activating and operating a plant and includes costs of salaried management personnel and an electrical fee. The electrical fee purchases sufficient electrical power to process that volume associated with the juncture of the linear segments constituting the plant-cost function (V_j). Consequently, marginal cost up to V_j is less than that beyond V_j.

Plants have the opportunity to increase weekly and seasonal output by employing multiple labor shifts. Thus, there are two levels of variable labor cost associated with each plant—one for the regular shifts and another for overtime labor shifts. If the capacity of the regular shift is exceeded, all of the additional cotton must be processed at the more expensive overtime rate. However, prudent use of overtime may be cost saving if it avoids the necessity of activating an additional plant.

Additional cost trade-offs exist between the region's number of operating plants and total assembly costs; that is, as plants are activated, the average assembly distance decreases,

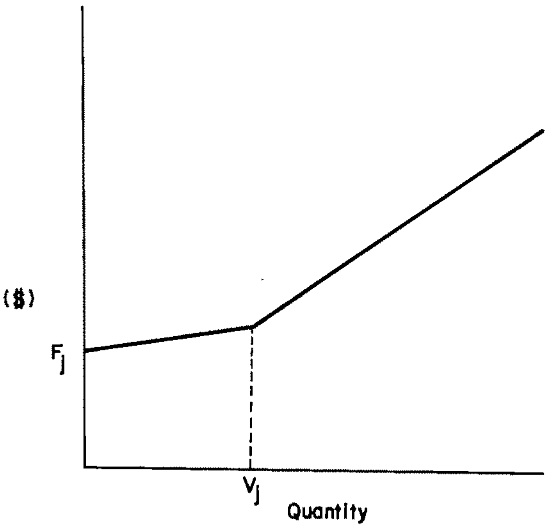

Figure 1. Total variable plant cost exclusive of variable labor cost

which affects reductions in assembly cost. In addition, reducing regional processing capacity below the peak-week harvest output necessitates the storage of seed cotton, thus adding an additional cost to the system. However, seed cotton storage may be preferable to activating an additional plant.

An optimal solution to the problem is one that minimizes aggregated costs of assembly, storage, and processing for the region's ginning industry. In particular, the solution must designate which plants to activate for the season, quantity of seed cotton to be field-stored, quantity of seed cotton to be assembled per week from specific production locations to activated plants, and the amount of cotton processed at each activated plant per week.

Mathematical Representation of the Problem

Let m represent the number of production locations, n the number of existing plants, and W the number of weeks in the planning period. The weekly quantities of raw product at each production location are known and are denoted by $P_{1k}, \ldots, P_{mk}$, where $k = 1, \ldots, W$. Also, the weekly capacities of each of the existing plants are known and are denoted as $K'_1, \ldots, K'_n$ for output processed during regular hours and $K''_1, \ldots, K''_n$ for output processed during overtime hours. Furthermore, let the costs at the jth plant be denoted by r'_j = marginal labor cost incurred

[1] Storage is accomplished with a rick compactor that forms a stack of seed cotton approximately 8 feet wide and 6 feet high at a density of 7 pounds per cubic foot. Once the peak harvesting period has passed, the stored seed cotton is loaded into trailers and shipped to operating plants for processing.

during regular hours, r''_j = marginal labor cost incurred during overtime hours, where $r'_j < r''_j$, F_j = annual fixed charge associated with activating plant j, c'_j = marginal cost exclusive of labor associated with plant j's initial linear cost segment, and c''_j = marginal cost exclusive of labor associated with plant j's second linear cost segment, where the juncture point between the two segments is at V_j for plant j and $c'_j < c''_j$.

The cost of placing the raw product into storage and then later removing it represents a one-time cost that is independent of the production origin, the activated plants, and the time period. Let S represent the unit storage cost. Furthermore, the assembly cost between each pair of production locations and existing plant sites is proportional to the quantity shipped and the distance between the production location and the plant site. Let t_{ij} represent the unit assembly cost from production location i to plant j's location site. The problem is to select a configuration R of the n existing plants such that the aggregated cost of assembly, storage, and processing is minimized and all raw material is processed without exceeding plant capacities.

To obtain a mathematical model of this problem, the following decision variables are defined: y_j = a binary variable where $y_j = 1$ when plant j is activated and $y_j = 0$ when plant j remains closed, X'_{ijk} = quantity of raw product available at production location i and processed at plant j in week k during regular hours, X''_{ijk} = quantity of raw product available at production location i and processed at plant j in week k during overtime hours, S'_{ijkl} = quantity of raw product stored at production location i in week k and then processed at plant j during regular hours in week l, and S''_{ijkl} = quantity of raw product stored at production location i in week k and then processed at plant j during overtime hours in week l. From these decision variables, it is possible to determine the total amount of raw product processed at plant j, (X_j). It is then possible to separate X_j as follows:

$$X'_j = \begin{cases} X_j \text{ if } X_j \le V_j \\ V_j \text{ if } X_j > V_j \end{cases}$$

and

$$X''_j = \begin{cases} 0 \text{ if } X_j \le V_j \\ X_j - V_j \text{ if } X_j > V_j \end{cases}.$$

Then the mathematical model of the problem is as follows. Determine the values of the decision variables such that total systems cost (Z) is minimized, where

$$\begin{aligned} Z = \sum_{j=1}^{n} y_j \Bigg[& F_j + c'_j X'_j + c_j V_j + c''_j X''_j \\ & + r'_j \left(\sum_{i=1}^{m} \left(\sum_{k=1}^{W} X'_{ijk} + \sum_{l=1}^{W} \sum_{k=1}^{l} S'_{ijkl} \right) \right) \\ & + r''_j \left(\sum_{i=1}^{m} \left(\sum_{k=1}^{W} X''_{ijk} + \sum_{l=1}^{W} \sum_{k=1}^{l} S''_{ijkl} \right) \right) \\ & + S \sum_{i=1}^{m} \sum_{l=1}^{W} \sum_{k=1}^{l} (S'_{ijkl} + S''_{ijkl}) \\ & + \sum_{i=1}^{m} \left(t_{ij} \left(\sum_{k=1}^{W} (X'_{ijk} + X''_{ijk}) \right. \right. \\ & \left. \left. + \sum_{l=1}^{W} \sum_{k=1}^{l} (S'_{ijkl} + S''_{ijkl}) \right) \right) \Bigg] \end{aligned}$$

is subject to the following conditions.

All raw product available at production location i in week k is either processed or stored,

$$\sum_{j=1}^{n} y_j \, (X'_{ijk} + X''_{ijk} + S'_{ijkl} + S''_{ijkl}) = P_{ik},$$

for $i = 1, \ldots, n$; $k = 1, \ldots, W$; and $l = k + 1, \ldots, W$. The plant's weekly processing capacity associated with regular processing hours must not be exceeded. For plant j in week l, this is

$$\sum_{i=1}^{m} (X'_{ijl} + \sum_{k=1}^{l-1} S'_{ijkl}) \le K'_j,$$

for $j = 1, \ldots, n$, and $l = 1, \ldots, W$. The plant's weekly processing capacity associated with overtime processing hours must not be exceeded. For plant j in week l, this is

$$\sum_{i=1}^{m} (X''_{ijl} + \sum_{k=1}^{l-1} S''_{ijkl}) \le K''_j,$$

for $j = 1, \ldots, n$, and $l = 1, \ldots, W$. Restrictions on the decision variables are $X'_{ijk} \ge 0$; $X''_{ijk} \ge 0$; $S'_{ijkl} \ge 0$; $S''_{ijkl} \ge 0$, and $y_j = 0$ or 1. To determine total seasonal output for plant j $(X'_j + X''_j)$, the following accounting equation is specified:

$$\sum_{i=1}^{m} \left(\sum_{i=1}^{m} (X'_{ijk} + X''_{ijk}) + \sum_{l=1}^{W} \sum_{k=1}^{l} (S'_{ijkl} + S''_{ijkl}) \right) = X_j,$$

for $j = 1, \ldots, n$.

The above mathematical model is a mixed integer 0-1 linear programming problem. Conceptually, the problem could be solved using a standard mixed-integer linear programming computer code. However, for the problem under consideration (139 production locations, 14 processing plants, and 16 production weeks), the problem dimensions exceed the solution capability of any known mixed-integer computer code. To the author's knowledge, the mixed-integer programming systems available from leading computer manufacturers are the most capable of any existing computer codes for solving large mixed-integer programming problems. Examples of these codes include the APEX III programming system available from the Control Data Corporation and the mixed-integer code available with International Business Machines Corporation's MPSX system. It is estimated that 800 computer hours would be required to solve the problem under consideration, given these mixed-integer computer codes capabilities.

Recent developments and computational testing have shown that special purpose computer codes for solving minimum-cost-flow network problems are 100 to 150 times faster than the best general purpose commercial linear programming computer codes; thus, the problem was reformulated as a network problem (Glover, Karney, and Klingman 1973). The following section presents a network formulation of the problem that is mathematically equivalent to the above formulation; that is, to formulate the problem as a network problem, no simplifying assumptions are made. Thus, solving either formulation of the problem will yield the same optimum.

Network Formulation

A network consists of a number of nodes or junction points, each joined to some or all of the others by arcs. Nodes are diagrammed as circles, while arcs are indicated by lines or line segments. The crossing of arcs does not indicate intersection of corresponding arcs except at nodes. The unidirectional flow of raw product is represented by an arrow placed on an arc. To exhibit the structure of the cost-flow network, a prototype of the above problem is formulated in figures 2 and 3. A portion of the network shown in figure 2 is enlarged and shown in figure 3.

The prototype problem involves two production locations that produce raw product for two consecutive weeks and two existing plants that may operate these two weeks plus one additional week. Level iAk nodes represent production location i in week k, while P_{ik} depicts the raw product produced at location i in week k. In the example, a total of four production nodes are represented. In addition, associated with each production location node are arcs that connect it with the jBl nodes, where the node jBl represents available processing at plant j during week l. On the arcs connecting the iAk level nodes with the jBl level nodes, there is the unit assembly (t_{ij}) and a one-time unit storage cost (S) if the value of l associated with the jBl level node is greater than the value of k associated with the iAk level node. All of the raw product processed in each plant during the three weeks is then channeled through a single node called the weekly master node for that plant. The jC level node corresponds to the weekly master node for plant j. Two arcs connect each jBl level node with the jC level node. One arc represents processing at plant j without use of overtime labor. Such arcs have a weekly capacity of K'_j and a unit cost of r'_j. The second arc represents weekly overtime processing capacity of K''_j and associated unit cost of r''_j.

To accommodate the two levels of marginal cost associated with the two linear segments comprising each plant's cost function, D level nodes are introduced. Two arcs connect each C and D level node. One arc is for the marginal cost c'_j and has a capacity given by volume V_j. This arc represents the jth plant's first linear-cost segment, while the second arc is for marginal cost c''_j and represents the second linear-cost segment.

Finally, all flow is channeled through a single node, node E, which acts as a sink for the entire raw product production. The arc from node jD to node E has an upper bound or capacity restraint of Uy_j on its flow, where U equals the sum of production of all production locations for the season and has a unit cost of 0 (figure 3). This capacity restraint has the following effect. If $y_j = 0$, then plant j cannot process any raw product during the entire season. Therefore, it is not activated. Otherwise, $y_j = 1$, and plant j can process any amount of raw product subject to the other restraints within the model.

Each arc in figure 3 has the marginal cost

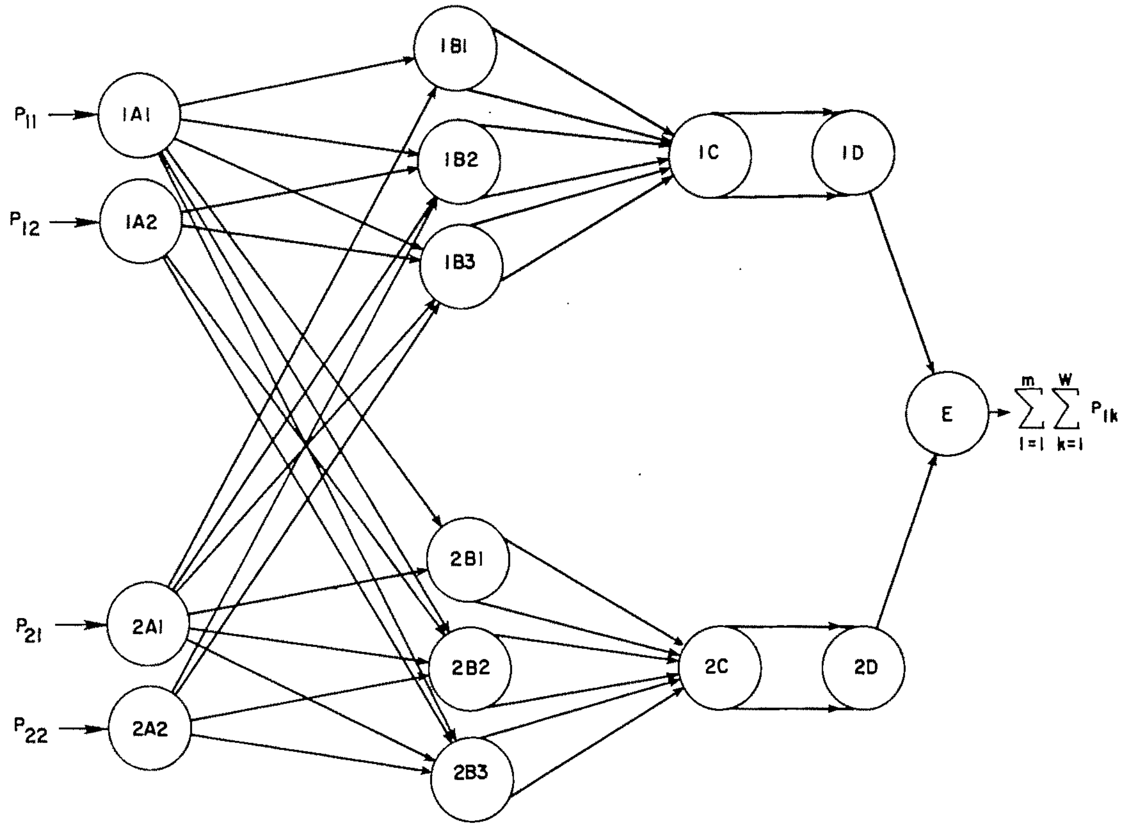

Figure 2. Network diagram of prototype problem

and the appropriate upper and lower bounds associated with each arc for that portion of the network associated with production location 1. Absence of a lower bound indicates a lower bound of 0. Plant capacities K'_j, K''_j, and V_j represent upper flow bounds. The network problem can be stated as follows: for a given set of plants, find the least-cost flow of goods through the network such that the flow does not violate the flow bounds on each arc.

Network Solution Procedure

The above network model can be solved as follows. Arbitrarily fix the value of the y_j variables to 0 or 1, then solve the remaining problem (the subproblem) to find a set of flows on the arcs that satisfy the capacity restrictions on the arcs and the input and output restrictions on the nodes at minimum cost. Once the values of the y_j variables have been selected, the subproblem to be solved is called a minimum-cost-flow network problem. A recently developed, highly efficient minimum-cost-flow network computer code by Glover, Klingman, and Karney was used to solve the subproblems (1974).

Conceptually, the solution procedure involves implicitly setting the y_j variables to every possible combination of values (0's or 1's) and solving the associated subproblem for each combination. After each subproblem has been solved, the total of the fixed charges for those plants scheduled for processing is then added to the total cost of the subproblem. The optimal solution is that one that is the minimum of all combinations.

The efficiency of this solution approach depends on the solution speed of the network code and the number of subproblems that actually have to be solved. The total number of subproblems is $2^n - 1$. Unfortunately, this number is often large, e.g., for $n = 14$, there is a total of 16,383 subproblems. In order to avoid explicitly solving all subproblems, a highly effective implicit enumeration procedure was employed. The following section gives an overview of this procedure.

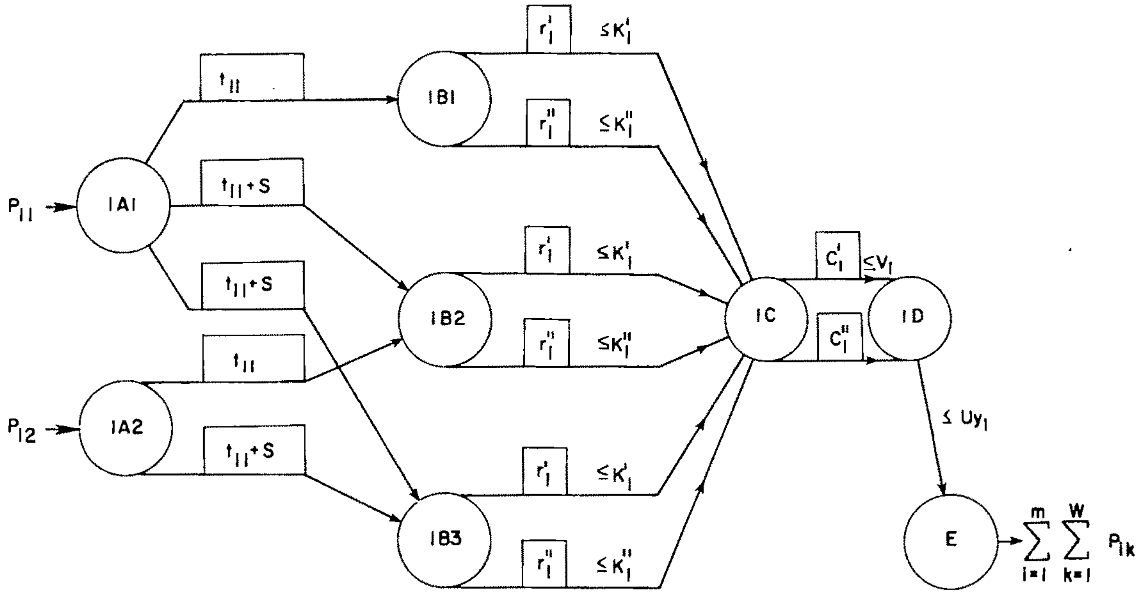

Figure 3. Enlarged network diagram of prototype problem for production location 1

Implicit Enumeration Procedure

Implicit enumeration is an organized method of complete enumeration in which only those combinations that can improve a previously enumerated combination are examined. To apply implicit enumeration, the problem is pictured as searching a logic tree composed of branches and nodes. The search proceeds along a branch until it becomes obvious that continued progress along a given branch is unnecessary because the best possible payoff on that branch can be shown to be inferior to payoffs already observed on other branches. In this way, only partial examination of most branches needs to be considered, thus significantly reducing the number of combinations considered.

To illustrate the concept of implicit enumeration, consider a prototype problem involving four plants (figure 4). The associated logic tree illustrates all combinations of plants that may be deactivated. Each node in the tree represents a combination of plants that are deactivated. Those plants not designated in a node are considered activated.

Fixed charges associated with activated plant combinations are aggregated with that combination's optimal assembly, storing, and processing costs determined via the network code. Node [0] in the logic tree corresponds to the least-cost solution found when all plants are activated and total costs are represented by TC_0. Node [1] represents the objective function value when the problem is optimized with plant 1 deactivated. Let TC_1 represent the resulting total cost. There are three possible outcomes (*a*) $TC_0 < TC_1$, in which case the removal of plant 1 has increased the costs being minimized. Thus, this branch may be removed from the tree, since the solution will always be improved by utilizing plant 1. Similarly, all nodes in other branches of the tree that do not have plant 1 operating may be removed. (*b*) $TC_0 > TC_1$, in which case the objective function value has decreased by deactivating plant 1. In this case, no nodes of the tree may be removed. Thus, one continues to move through this branch of the logic tree. (*c*) The solution is infeasible with plant 1 deactivated. In this case, as in case 1, this branch of the tree and all nodes in other branches that do not utilize plant 1 may be removed.

When all branches have been explicitly or implicitly traced, the last nodes of each branch are compared to each other. The node with the smallest objective function value represents the optimal plant combination.

The specific techniques for implicit enumeration vary widely among problems, and the above general description represents a simplification of the technique actually used in this problem. For details of the employed branching rules, see Klingman, Randolph, and Fuller. Table 1 contains solution time statistics on several problems to illustrate the ef-

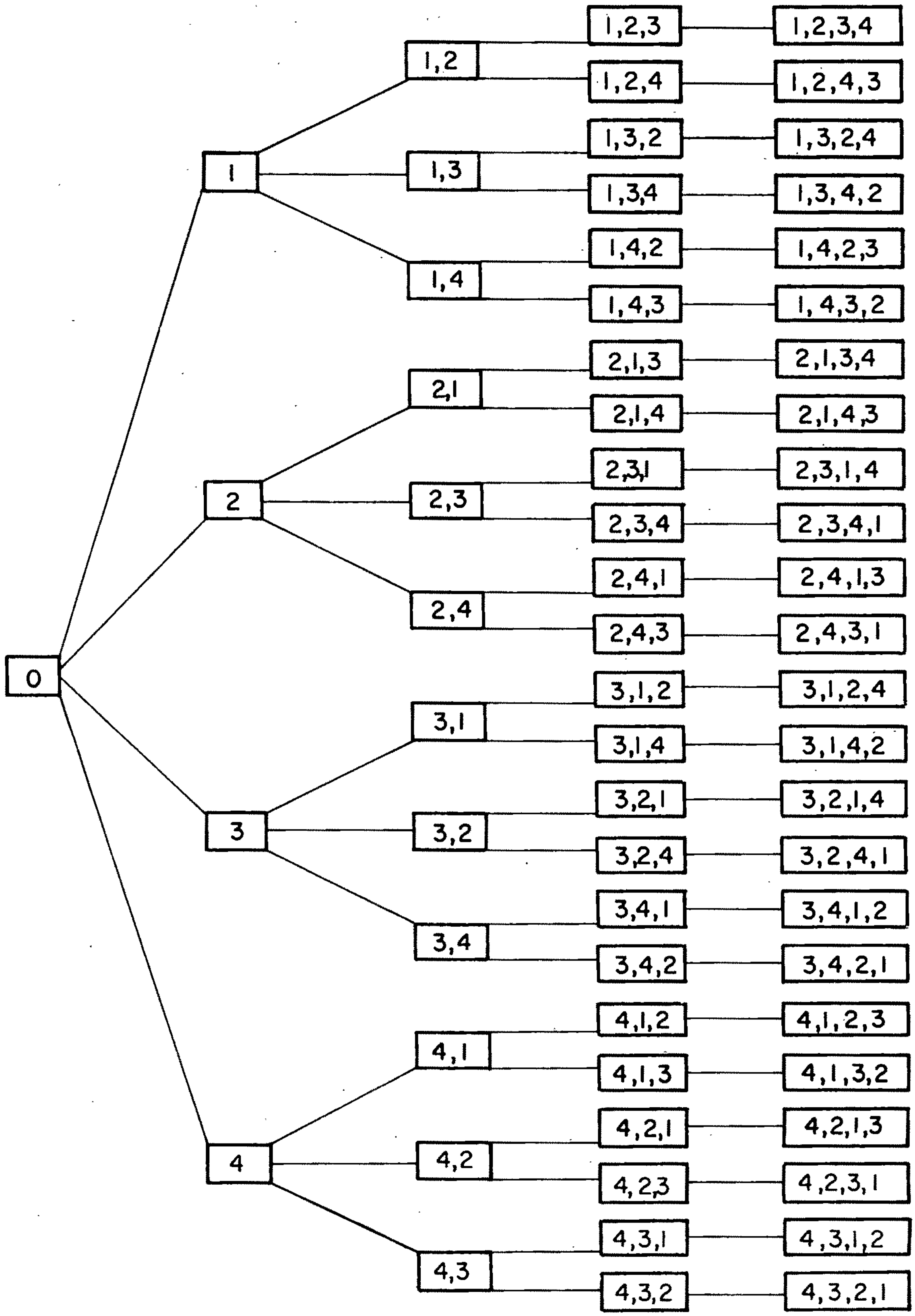

Figure 4. Logic tree for prototype problem involving four plants

Table 1. Solution Time Statistics

Production Locations (m)	Plants (n)	Weeks (W)	Solution Times[a] (sec.)	Number of Subproblems Solved
30	5	14	10.1	9
30	10	14	36.3	27
45	10	14	65.4	21
45	15	14	65.6	31
78	15	16	298.7	37

[a] Solution times on a CDC 6600.

ficiency of both the network code and the implicit enumeration procedure.[2] The solution times indicate that it is quite feasible to solve large problems of this type.

Application Results

The ginning industry under study is located in an irrigated portion of the Rio Grande Valley that traverses Texas and New Mexico. The study area is approximately 90 miles in length and varies from 1/4 to 7 miles in width. Fourteen single plant firms currently operate in this area and process the area's 43,000 bales of annual production. In the early 1960s, the study area produced approximately 85,000 bales, which were processed at sixteen area plants. Because of the relative stability of the area's processing capacity, excess plant capacity has developed. Furthermore, recent innovations in seed cotton storage would permit reductions in gin plant numbers by removing the interdependence of harvesting and ginning activities. The above model was applied to this situation to resolve least-cost industry organization.

A substantial resource commitment was necessary to develop data inputs for this model application. A 139 × 14 matrix relating production, production locations, and distance to existing gin sites was developed from aerial photos and Agricultural Stabilization and Conservation Service data. Work measurement data was collected on the fourteen plants by the work sampling technique. Input-output parameters for energy, plant downtime and physical capacity utilization characteristics, and other technical aspects of production affecting variable cost were obtained by monitoring plants throughout the 1973–74 season (Fuller and Washburn). The assembly activity's production characteristics were recorded on the area system, while the storage system input-output parameters were determined by monitoring an area that had previously adopted this technology. Once production functions had been specified, the cost functions were determined by applying factor prices. The plant's cost and physical capacity characteristics are shown in table 2. Storage and assembly costs were estimated to be \$6.01 per stored bale and \$0.42 per bale-mile, respectively.

Because of the ginning industry's excess processing capacity, all plants will not need to operate to accommodate the peak-harvest output level. Therefore, some reduction in plant numbers and associated plant cost would be available without introduction of seed cotton storage. To separate those plant cost savings attributable to removal of excess processing capacity from those due to the seed cotton storage technology, three alternative solutions were resolved. The first solution was a simulation of the existing system costs (assembly and processing) and involved the fourteen gin plants operating at their 1974 output levels. The second solution was the optimal organization attainable with the opportunity for storage. The third solution reflected the optimal industry organization attainable without the opportunity for storage. This was accomplished by removing storage arcs between the A and B level nodes. By contrasting the three solutions, cost savings available with the removal of excess plant capacity and introduction of seed cotton storage technology were isolated (table 3).

Optimum Industry Organization with Storage

The optimum industry organization involved the operation of six plants (plants A, E, G, H, J, and M) rather than the existing fourteen. To increase the activated plants' annual volume, approximately 7% of the region's cotton production was processed during overtime shifts, whereas slightly over 10% of the production was stored. Utilization of overtime shifts and storage occurred during peak-harvest weeks when harvested output exceeded processing capacity. Immediately following peak-week harvest output, cotton was removed from storage and processed during the plants' regu-

[2] The computer system is proprietary. Information on the availability of the code may be obtained by contacting Professor Darwin Klingman, BEB-608, University of Texas, Austin, Texas 78712.

Table 2. Study Area Plant's Cost and Physical Capacity Characteristics, 1975

Plant	Fixed Charge[a] (F_j)	Unit Cost Associated with Initial Plant Cost Function Segment and Labor Cost Incurred in Regular Hours[b] ($c'_j + r'_j$)	Unit Cost Associated with Second Plant Cost Function Segment and Labor Cost Incurred in Regular Hours[b] ($c''_j + r'_j$)	Unit Labor Cost Incurred in Overtime Hours (r''_j)	Volume Associated with Intersection of Plant Cost Function Segments[c] (V_j)	Plant's per Week Capacity without Overtime Labor (K'_j)	Plant's per Week Capacity with Overtime Labor (K''_j)
	$				Bales		
A	19,788	4.70	5.45	5.01	3,436	630	735
B	19,790	5,18	6.61	5.79	2,283	540	630
C	21,666	5.26	7.41	6.39	2,392	585	682
D	20,124	5.21	7.35	6.30	1,683	450	525
E	21,906	5.80	7.13	5.52	4,047	675	787
F	18,918	7.28	8.47	7.29	2,012	495	577
G	20,928	5.42	6.76	5.07	3,287	657	766
H	19,014	6.03	7.05	5.10	2,442	585	682
I	18.174	5.80	6.61	6.60	2,038	504	588
J	18,906	5.75	6.93	6.57	2,019	450	525
K	18,690	8.24	8.83	9.75	3,672	495	577
L	20,142	6.28	7.79	6.36	2,397	540	630
M	18,981	5.82	6.82	5.22	2,458	540	630
N	19,740	5.76	7.07	5.67	2,456	585	682

[a] Includes cost of salaried management personnel and an electrical fee.
[b] Includes those variable costs that tended to vary between plants—seasonal office and gin plant labor, utilities, repairs, and drying fuel. Does not include plant fixed cost, bagging and ties, office supplies, office utilities, advertising, travel, and miscellaneous costs.
[c] See figure 1.

lar labor shifts. In addition, each activated plant remained open throughout the sixteen-week harvest season; i.e., plants were not opened and closed weekly as the solution procedure permitted.

The six activated plants were on the average of slightly greater capacity and lower unit variable cost than the closed facilities. As shown in table 2, the activated plants were generally the most labor efficient. Even though the plant's annual fixed charges must have strongly influenced optimal plant numbers, they varied little between plants and accordingly had an insignificant effect on plant selection. Storage cost was favorably affected by selecting larger than average plant sizes, since this reduced the quantity of seed cotton that required storage. Storage was system-cost reducing; however, additional storage could have been utilized. With additional storage, several more plants could have been deactivated, as twenty-two weeks were available for processing. Clearly, cost savings (fixed charges) associated with further reductions in plant numbers failed to offset increases in storage, assembly, and overtime labor costs. In addition, the optimal solution revealed several effects of assembly costs. First, the locational configuration of selected plants closely approximated one predicted by a priori rea-

Table 3. Contrasted Characteristics of Actual and Optimum Short-Run Industry Organizations

Organization	Number of Operated Plants	Plant Cost[a]	Storage Cost[b]	Assembly Cost[b]	Total System Cost
		$			
Actual	14	528,122	0	69,167	597,289
Optimum without storage	9	445,065	0	71,326	516,391
Optimum with storage	6	393,018	26,786	80,970	500,775

[a] Includes those variable costs that tend to vary between plants—seasonal office and gin plant labor, utilities, repairs, and drying fuel. Does not include plant fixed costs, bagging and ties, office supplies, office utilities, advertising, travel, and miscellaneous costs.
[b] Includes fixed and variable costs.

soning; i.e., plants were evenly dispersed throughout the production region with modification for locational pull associated with more intensive production areas. Second, in those weeks when processing capacity exceeded processing demand, cotton could have been routed to the more efficient of the six selected plants, i.e., the least efficient plants could have been closed. Since this did not occur, this implies that processing cost savings failed to offset assembly costs associated with the additional assembly distances.

Optimum Industry Organization without Storage

The optimum solution reflects industry organization with excess plant capacity removed. Characteristics of this solution are similar to that solution involving storage. The optimal organization involved the operation of nine plants, six of which were identical to those activated in the storage solution. Activated plants were A, C, E, G, H, I, J, M, and N. Approximately 4% of the region's cotton production was processed during overtime shifts that were used in those weeks when harvested output exceeded processing capacity. Again, the solution revealed no cost advantage to opening and closing plants on a weekly basis.

The optimal organization revealed that system costs were minimized by reducing plant numbers to the maximum feasible extent. Reducing area plant numbers so that industry processing capacity is just capable of meeting peak-week harvested output through use of overtime labor shifts was cost advantageous. Gin plant cost savings, associated with reducing plant numbers, more than offset increases in assembly and overtime labor costs.

Implementation and Implication of Solutions

The analysis indicates that most of the potential savings can be realized by reorganizing the study area ginning industry to reflect removal of its excess capacity; that is, seed cotton storage technology need not be introduced. Adopting the reorganization scheme that involves no storage would reduce system costs $1.88 per bale, a saving of 14%. This alternative could be implemented without investment in new capital. The reorganization alternative that involves storage would yield a saving of $0.36 per bale relative to the organization involving no storage. Based on existing cotton production levels and on savings attributable to storage, approximately seven years would be required to capture capital expenditure associated with implementation of this alternative. Because of the study area's declining cotton production, decision makers are not inclined to invest new capital into the area's cotton-marketing system. Consequently, the reorganization scheme requiring no storage would appear most acceptable.

Currently, the study area ginning industry is comprised of fourteen single gin plant firms—eleven of these firms are producer cooperatives, while the remaining firms are partnerships. Because of the fragmented ownership structure of the study area industry, implementation of either scheme would require some firms to exit the industry or merge with remaining firms. For example, to implement the no-storage solution, three cooperatives and two partnerships would need to cease gin plant operation. It is difficult to predict whether either reorganization alternative will be implemented. During the past several years, personnel from the Extension Service have counseled with study area gin firms in an effort to thwart their deteriorating financial condition. Merger has been the principal alternative forwarded by extension personnel. Merger is a vehicle whereby much of the potential savings could be realized, since this would permit closing of the least efficient plants and/or reduction in gin plant management personnel, the principal source of savings. The results of this study have not been presented to the area decision makers; however, past efforts to bring firms together for merger negotiation have been unsuccessful. One of the undesirable effects of taking no action rests with the unfavorable efficiency characteristics of the financially strong firms. The newer, more efficient gin plants are owned by firms with the heaviest debt load and appear to be the first to exit the area industry. These plants may never reopen, since the remaining firms may prefer to operate the plants located within their immediate communities.

Optimizing subindustry spatial organization leads to the allocation of exclusive market areas, in which case there is an unavoidable conflict between competition and efficiency that stems from the element of spatial

monopoly. Therefore, operational efficiency gains may be offset by losses in pricing efficiency. Introducing either reorganization alternative into the study area may result in pricing efficiency losses; however, several circumstances reduce this threat. Ginning charges are monitored by a state agency that annually holds hearings for testimony on the fairness of charges proposed by area ginning industries. Consequently, excessive charges should not occur. In addition, the evolved ginning industry would probably include farmer-owned cooperatives, given the existing dominance of this form of business, in which case the threat of monopolistic power directed toward producers is diminished.

Summary

As applied economists endeavor to include additional realism into their locational analysis, conventional solution techniques become limiting and unaccommodating. The plant-location problem involved consideration of several dimensions not conveniently incorporated into existing location models. The problem involved consideration of (*a*) short-run costs unique to each plant but whose general form was piecewise linear with an annual fixed charge, (*b*) two levels of variable labor cost associated with regular and overtime work shifts and each shift's weekly output constraint, (*c*) storage cost, and (*d*) assembly cost between each pair of production locations and plant sites. The least-cost solution identified plants to be activated at alternative sites and quantity processed per week, weekly quantity processed at each plant in regular and overtime shifts, and the quantity to be stored per week.

To attain the desired realism in the model and to find a workable algorithm, the problem was formulated as a network problem and solved with a network computer code. This network abstraction not only provided greater insight into the structure of the problem but also opened the way to a feasible computer solution. Such an abstraction if applied to other locational problems should prove to be equally effective. Because a network model can easily accommodate a multiphase problem, it is less necessary to make certain simplifying and unrealistic assumptions. Furthermore, the computational efficiency gained by employing the network algorithm with implicit enumeration permits the investigation of larger locational problems than traditional solution approaches.

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A Spatial Equilibrium Model for Plant Location and Interregional Trade

Matthias von Oppen and John T. Scott

Combination of a single-equation location model and interregional trade analysis into one model provides an effective tool to simultaneously determine regionally optimal numbers and sizes of processing plants and optimal interregional trading and pricing. The results of an earlier empirical application of the model on the prospective soybean industry in India are reviewed after four years of actual development. Private industry is allocating its processing plants in line with the pattern computed by the model, and a comparatively costly plan of arbitrarily establishing one government plant at an arbitrary location has not been implemented.

Key words: agricultural industry, India, interregional trade, location theory, soybeans.

The general theory pertaining to the spatial location of economic activity can be divided, according to Hoover, into the following three classes: location, regional analysis, and interregional trade. Location theory describes the economic analysis involved in comparing alternative spatial locations for a specified kind of activity, while regional analysis is "concerned with groupings of inter-related economic activities in proximity within certain specified areas" (Hoover, p. 3). Interregional trade refers to the buying and selling of inputs or products and their movement among two or more delineated areas.

Highly sophisticated methods and approaches have been separately developed in each of these fields of spatial economic theory. However, apparently few attempts have been made to integrate these theoretic fields, especially the theory of location and interregional trade analysis, or to integrate their associated models (Candler, Snyder, and Faught; Leuthold and Bawden; Rao; Stammer).

There are an increasing number of cases in which public decision makers, especially in developing countries, are concerned with the question of implementing a new, efficient agricultural industry (from raw materials production to processing and marketing of final products) so that social welfare can be maximized. To solve such a problem requires investigations in two fields: (*a*) an analysis of the interregional trade in order to predict the flows of the new goods, the quantities demanded regionally, and the resulting price level; and (*b*) a determination of optimal locations and sizes of individual processing plants. Therefore, we believe that an approach integrating the theory of location and interregional trade analysis will be of general interest. The model presented here was developed to represent the emerging soybean industry in India (von Oppen 1972), but it could be adopted to almost any agricultural production and processing industry.

The Model

The spatial equilibrium model for location of processing plants integrates all of the following important economic functions: (*a*) transportation of inputs and products, (*b*) average processing cost related to plant size, (*c*) size of market area per plant, (*d*) regional supply functions of inputs to be processed, and (*e*) regional consumer demand functions for processed products. The model is constructed in two parts: the plant location is determined with the help of a single equation optimization model and the interregional trade of inputs and products is analyzed by means of a quadratic

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programming model. From the optimum solution of the plant location, model regional average processing costs are derived and fed into the interregional trade model. From the optimum solutions of interregional trade model, the quantities to be processed and distributed by processing plants are derived and fed into the plant location model. If applied in this fashion, both models are linked by an iterative solution procedure and jointly form a spatial equilibrium model for plant location and interregional trade (figure 1).

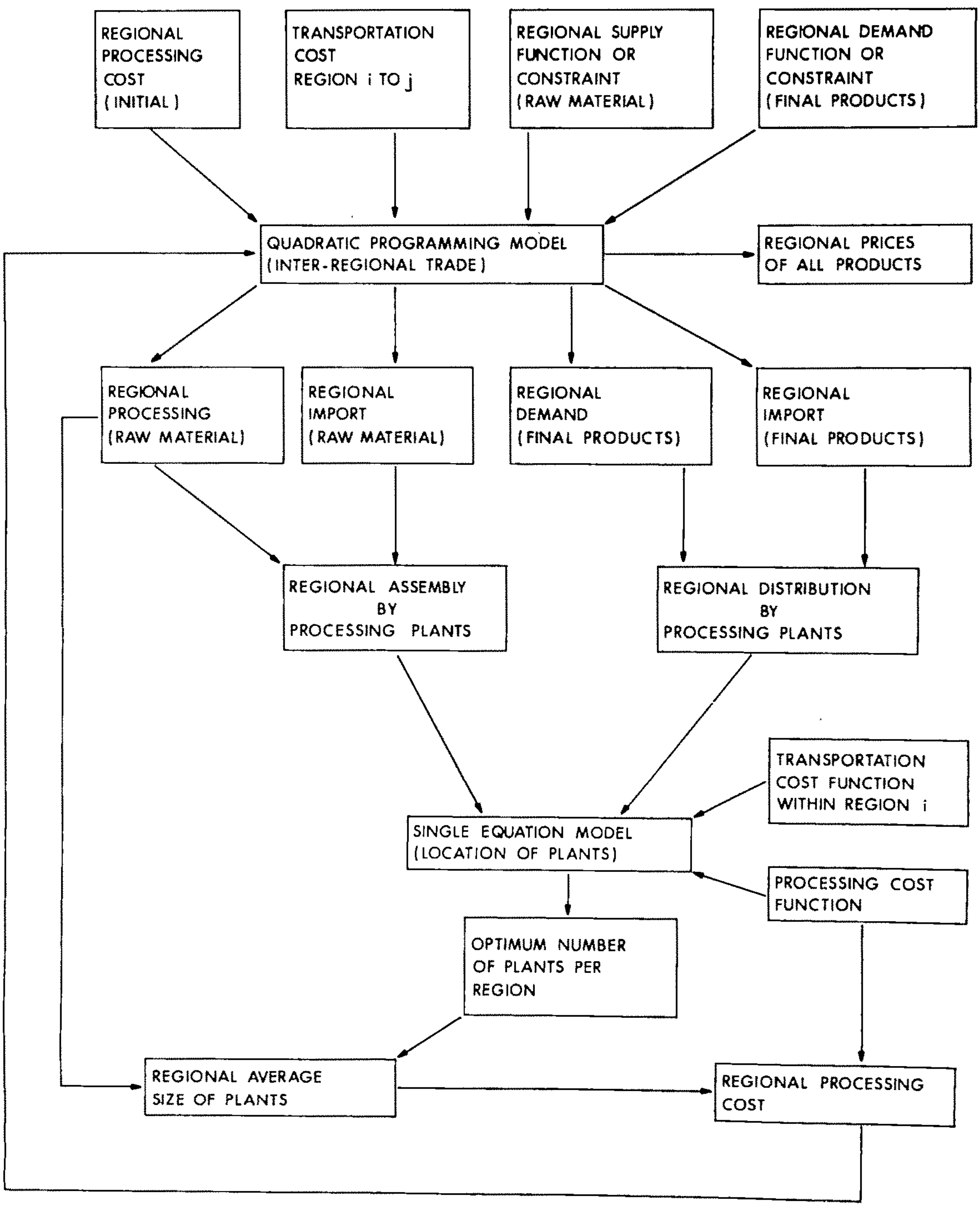

Figure 1. Flow chart of a spatial equilibrium model for plant location and interregional trade

Plant Location—Assembly, Processing, and Distribution

The location equation is based on the following assumptions: (*a*) as the number of plants within a region increases, average processing costs will increase at a linear rate; (*b*) both the average assembly and distribution costs of the major inputs and products in the market area of a plant decrease at a decreasing rate as the number of plants in a region increases; (*c*) the assembly and distribution road network fits approximately a 60° triangular grid such that hexogonally-shaped plant market areas within regions are appropriate; and (*d*) within a region, producers of inputs for the plant and consumers of products from the plant are evenly distributed.[1]

Furthermore, as the number of plants is initially increased (from the number at which plant size is large enough that average processing cost is a minimum), the sum of average assembly and distribution costs decreases faster than the increases in average processing cost. As the number of plants continues to increase, however, processing costs begin to increase faster than the decrease in assembly and distribution costs. The optimum number of evenly distributed plants is determined by the minimum of the sum of these average cost functions.

Given these assumptions, the plant location equation can be derived as follows:

$$B = 6\frac{r^2}{4}3^{1/2}, \tag{1}$$

where B = the hexagonal market area for a plant and r = the circumscribing radius of the hexagon. If A is the total area of the region for which the optimum number of plants is to be found and N is the number of plants, the area per plant can be explained as

$$B = \frac{A}{N}. \tag{2}$$

Solving equation (1) for r and substituting equation (2) into (1) gives

$$r = 0.6204\left(\frac{A}{N}\right)^{1/2} \tag{3}$$

for the radius of each of the N hexagons representing the market areas of the plants in the region. The average distance from all points evenly distributed within the hexagon to the central point for assembly and distribution can be shown to be $0.7r$.

We assume that assembly of raw material and distribution of final products have the same per unit costs and these are a linear function of the average distance from the plant with an initial fixed cost for loading or unloading and vehicle use, so that

$$T = f + d\,(0.7r), \tag{4}$$

where T = the transportation cost per unit of input or product, f = the fixed cost, and d = the per unit cost of transportation per unit distance.[2]

The quantities of raw materials (R) to be assembled for processing and the quantities of final products (M) to be distributed for consumption within the market area of the plant can be expressed in relative terms using as a common denominator the quantity regionally available for processing (Q).[3] Relative weights of the quantities transported within the market area of a plant are required to form the sum of the transportation cost functions for both of these quantities before adding the processing cost function. Thus, after substituting equation (3) into equation (4) and multiplying by the relative weights, the regional assembly cost function for locally assembled input R becomes

$$T_1 = T\frac{R}{Q} = f_1\frac{R}{Q} + (0.43)\,d\left(\frac{R}{Q}\right)A^{1/2}N^{-1/2}, \tag{5}$$

and the regional distribution cost function for locally distributed final product M becomes

$$T_2 = T\frac{M}{Q} = f_2\frac{M}{Q} + (0.43)\,d\left(\frac{M}{Q}\right)A^{1/2}N^{-1/2}. \tag{6}$$

The average regional processing cost is assumed to be

$$T_3 = f_3 + c\,\frac{N}{Q}, \tag{7}$$

[1] This assumption is perfectly fulfilled only in the case of perfectly homogeneous (i.e., for all practical purposes, very small) regions. However, even in the case of larger regions with urban population concentrations, the assumption may still be acceptable and realistic as long as these urban areas as such are evenly distributed.

[2] Where assembly and distribution are carried out by truck and as long as the commodities concerned are not extremely bulky, perishable, or otherwise difficult to be transported by truck, their freight rates normally are based on the same per quintal charge.

[3] Note that Q includes regional production adjusted by imports and exports of the region as determined from the interregional trade portion of the model (see figure 1).

where N/Q = the reciprocal of average plant capacity, and the processing cost is assumed to be a function of the reciprocal of the quantity processed.[4] Then summing the three functions (5), (6), and (7) and setting the first derivative of this sum with respect to N equal to 0 gives the number of plants (N^*) that according to the second order condition minimizes assembly, processing, and distribution costs:

$$(8)\quad N^* = \left(\frac{0.43}{2}\ \frac{d}{c}\ (R + M)\right)^{2/3} A^{1/3}.$$

This shows that the optimum number of plants is a linear homogeneous function of degree one in the two variables—the sum of inputs assembled and products distributed and the area of the region. This optimum number is then theoretically located by evenly distributing the plants within the region.

Interregional Trade—Regional Supply and Demand Functions

The basic concept of this model is a special case of the general problem of nonlinear programming, which is solved for the saddle point (Takayama and Judge 1971). In this case the objective function is a quadratic function constrained by linear inequalities, a problem that has a unique solution (Takayama and Judge 1964).

The major assumptions and the economic environment are as follows. A given country is divided into n regions. Each region is represented by one base point at which the supply of primary product, the demand for the final products, and the processing capacity are assumed to be concentrated. All possible pairs of regions are separated by known transportation costs per physical unit for each product. The processing capacity in each region is assumed to be unlimited. Processing is performed at per unit costs that are assumed to be given for each region (from above). Demand for each of the final products is assumed to be known for each region and to be a logarithmic function of price.[5] For each of the n regions a nonnegative quantity of the primary product is given.

In this environment it is possible to formulate a model that accounts for the interaction of the spatially separated economic units. The model determines the level and location of processing of the primary product into final products, gives volume and direction of all product flows that will minimize the aggregate transportation and processing cost, and finally determines the pricing system of all products that accompany the optimum allocation system.

Regional demands for final commodities Y are assumed to be represented by functions dependent on price P. These are of the general form $P = aY^{-b}$. Their tangents represent linear demand functions for the final products in each region. By applying the familiar technique of formulating the "net" social benefit function as the sum of the line integrals of individual demand relations minus the total costs of processing and transportation, a quadratic spatial equilibrium problem can be set up (Takayama and Judge 1971). The objective of this problem is to maximize the "net" social benefit subject to a set of constraints on primary commodity allocation and flows; final commodity production, flows, and consumption; and processing and joint production. All prices and quantities are restricted to be nonnegative.

If the assumptions of the net benefit function and the constraints are satisfied, then a necessary and sufficient condition for an optimum solution to the problem is that the corresponding Lagrangian forms a saddle point. The appropriate Kuhn-Tucker conditions ensure that the solution is a maximum (Takayama and Judge 1964).

Combination of the Model Parts

When the two models are applied jointly, it is assumed that interregional flows take place between regional centers (reference points), while in reality, of course, shipments would flow from all plant centers or local assembly points (in case unprocessed raw products are shipped) to consumption centers. This assumption is justified because it implies realistically that the sum of the costs of all shipments between all pairs of plant centers and assembly points in region i and consumption centers in region j does not, or only to a negligible extent, differ from the costs of shipment between the regional centers of regions i and j.

In combining the two parts of the model into

[4] This functional form is suitable for estimating average cost functions of production processes where economies of size imply that with increasing capacity processing costs are asymptotically approaching a minimum value.

[5] For programming purposes this nonlinear function is assumed to be represented by its linear tangents. The incorporation into the model of the procedure for selecting the representative tangents is described in note 6.

one spatial equilibrium model, the following concept is applied. Assume that there are two systems that are mutually dependent in that the output of one constitutes part of the input of the other. Then, as these systems are optimization models, they form a combined equilibrium model. Their interdependence generates a sequential set of objectives and restrictions, the objective of the plant location model forming a restriction to the interregional trade model and the objective of the interregional trade model forming a restriction to the plant location model. In other words, for each of the two models the optimum solution is to be found subject to the constraint that the other model be optimized. Since part of the input of the model is generated by the other model, a sequence of alternating applications of both models—one in the objective, the other in the constraint, and vice versa—asymptotically approaches an equilibrium solution.[6] We assume that the solution is unique because each of the two parts of this model has a unique solution. Application of the model with empirical data showed consistent convergence of these solutions.[7]

[6] The spatial equilibrium model consists of the following programs: (*a*) quadratic programming model (*QP*), (*b*) single-equation plant location model (*SE*), (*c*) derivation of regional demand functions from a tangent to the exponential demand function (*DT*), and (*d*) testing of the tangent for representativeness and if rejected finding new tangent (*TT*). In applying these programs in the empirical case given below. The most efficient sequence was found to be

$$\begin{matrix} SE_1 \searrow \\ \quad QP_1 \rightarrow SE_2 \rightarrow QP_2 \rightarrow TT_1 \rightarrow QP_3 \rightarrow SE_3. \\ DT_1 \nearrow \end{matrix}$$

[7] The uniqueness of the solution depends upon the character of the set of the various parameters included. In the unlikely but conceivable case in which the parameters included generate nonconvergence of the results (e.g., when the sum of the costs of transportation of the raw materials equals the sum of the costs of the transportation of the final commodities), there would be no unique optimal solution to the problem. By submitting the model to appropriate sensitivity tests, the likelihood of such cases can be evaluated.

An Empirical Application

While there is a sophisticated oilseed processing industry established in India, soybean production, processing, and consumption is a new developing sector in this country. After their introduction in the late 1960s, cream-colored varieties of soybeans covered about 10,000 hectares in 1970–71 and about 43,000 hectares in 1973–74. In 1974, five solvent-extraction plants with a total capacity of 265 tons per day and five screw-press-expeller plants with a total capacity of 11 tons per day were reported to be processing soybeans in India (see table 1).

In view of this development it seems worthwhile to review the results that were generated in 1971 by the above spatial equilibrium model of a future Indian soybean economy based on data collected in 1970–71 (von Oppen 1972). The following is a summary of the major assumptions made on supply demand, transportation, and processing of soybeans (von Oppen 1972, 1974).

Based upon certain agronomic assumptions about the general production potential for soybeans in India, about the extent to which a selected number of crops and fallow land might be substituted by soybeans, and about

Table 1. Soybean Processing Facilities Reported in Different Regions in India—1974

	Region							
Plant Type	1	2	3	4	5	6	7	All-India
Screw-press expeller								
Number	—	1	—	2[a]	—	1	3	5
Average capacity (tons/day)	—	4	—		—	4	1	2.2
Annual capacity (tons)	—	800	—		—	800	600	2,200
Solvent extraction								
Number	—	1	—	1	—	2	1	5
Average capacity (tons/day)	—	60	—	60	—	10	125	53
Annual capacity (tons)	—	18,000	—	18,000	—	6,000	37,500	79,500
Total annual capacity (tons)	—	18,800	—	18,000	—	6,800	38,100	81,700

Source: Rathod and Motiramani 1974.
[a] One extrusion cooker and one soymilk plant, both still in the experimental stage.

yield, the potential production of soybeans by districts was computed (see figure 2); coterminous districts of homogeneous potential production densities were grouped into seven regions and the share of each region in the total potential production was calculated.[8]

The two joint products, soymeal and soyoil, were assumed to be substitutes for gram flour and groundnut oil, respectively, for each of which demand functions were fitted using time-series data on prices, quantities consumed per capita, and income per capita. The per capita demand for gram flour was estimated, and after conversion into the required form it became

$$P_g = 1.5716\ Y_g^{\ -0.84048},$$

where P_g = price of gram in rupees per kilogram and Y_g = the quantity of gram consumed in kilograms per capita.[9]

The per capita demand for groundnut oil used by the vanaspati[10] industry was estimated, and after conversion into the required form it became

$$P_o = 0.001955\ Y_o^{-1.8298},$$

where P_o = the price of groundnut oil in rupees per kilogram and Y_o = the quantity consumed in kilograms per capita.[11] The demand functions entered into the model were defined as tangents uniquely representing these exponential functions. Regional demands were then derived by dividing the slope of the soymeal demand by regional population, by dividing the slope of the soyoil demand from the vanaspati industry by regional population proportional to vanaspati industry prevailing in each region, and by adjusting the intercept of the soyoil demand function according to the postulated per capita income.[12]

The average costs of processing in solvent extraction plants were estimated from engineering data and found to be $T_3 = 59.95 + 1383.5\ S^{-1}$.[13] Assembly of soybeans from the farmer to the plant and distribution of soymeal from the plant to the consumers was assumed to be carried out by truck; truck rates were found to be a linear function of distance. The intraregional transport was assumed to be carried out by rail according to freight rates for the different commodities in 1970–71.

Table 2 summarizes the major assumptions made with respect to time. The years 1970–71, 1973–74, 1978–79, and 1988–89 are labeled model years A, B, C, and D, respectively. Estimates of the Indian population are taken from official sources. Estimates of income per capita are based on an average annual income between 1964 and 1969 and a compound growth rate of 2% annually during the entire period is assumed. Table 2 also gives the most recent data available on the actual development in 1971 and 1973.

Comparison of the actual development with the model years indicates that in 1973 population, income, and soybean production have developed about three years past the model year A and are about five years "away" from model year B. Therefore, the results (table 3) for model years A and B should be comparable with the actual location and size of soybean processing plants; if so, the results for the later model years C and D would allow one to draw useful conclusions.

Average processing capacity of soybean solvent extraction plants was calculated by the model to grow about 50 tons per day in year A to about 140 tons per day in year B, eventually reaching up to 350 to 400 tons per day in year D. Present capacities of the five solvent extraction plants for soybeans of 53 tons per day seem to be quite in line with this result, even though they range from 10 to 125 tons per day (table 1).

The existing processing plants are located in regions 2, 4, 6, and 7, which is partly in line with our predictions. In contradiction to the

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[8] Formulation of the interregional trade of a soybean economy (one raw product, two final products) into a quadratic programming model as specified above requires a matrix for n regions of $n \times 7$ rows and $n \times 23$ columns. Seven regions were chosen because on the one hand a larger number of regions would have required excessive computational costs and on the other hand less than seven regions would not have allowed a satisfactory division of the country into reasonably homogeneous areas.

[9] The function was estimated by using seventeen years of All-India per capita net availability and annual average prices of gram (Government of India 1968, 1970, and 1973). The standard error of the exponent is 0.1812, the coefficient of multiple correlation is 0.76, and the F-ratio is 21.5.

[10] Vanaspati, hydrogenated vegetable oil, is commonly used as cooking margarine in India.

[11] The estimation was based on monthly observations for five years (1964 to 1969) on per capita groundnut oil consumption (Q_o), groundnut oil prices (P_o), and per capita income expressed in vanaspati consumption per capita (V_c) (Government of India 1964 to 1969). After adjusting for an autocorrelation of 0.6, the logarithmic function fitted gives

$$\ln Q_o = \underset{(0.4004)}{-0.8590} - \underset{(0.2213)}{0.5465} \ln P_o + \underset{(0.254)}{0.653} \ln V_c.$$

Standard errors are given in parentheses. The coefficient of multiple correlation is 0.37 and the F-ratio is 5.3.

[12] Division of the slope of the soymeal demand by population implies multiplication of the per capita quantity and thus aggregation of the demand function.

[13] Where S represents annual capacity in tons, note that $S = QN^{-1}$.

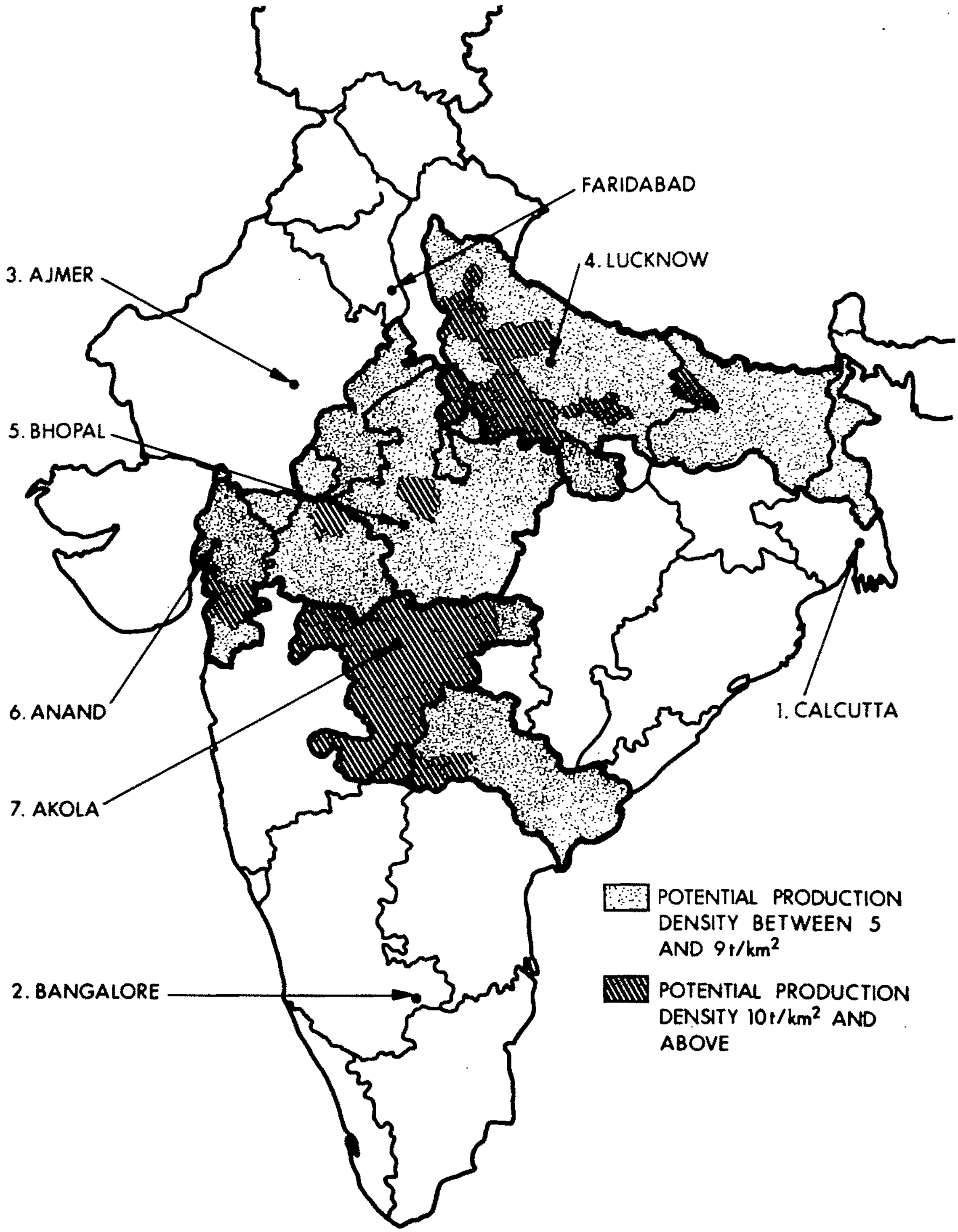

Figure 2. Estimated soybean production potential and demarcation of regions and reference points in India

model result, there is no processing capacity for soybeans in region 5 as yet, while in region 2 soybeans are processed. This can probably be explained by the fact that a reclassification of rail rates in 1973 resulted in a reduction of the rates for soybeans and a substantial in-

Table 2. Assumed and Actual Development in Population, Income, and Soybean Production

	Assumed Development in Model Years				Actual Development	
Item	A	B	C	D	1971	1973
Population in millions	550	592	662	787	551	574
(1968–69 = 100)	(105.0)	(113.0)	(126.3)	(150.2)	(105.2)	(109.5)
Income at 1960–61 prices						
in Rs. per capita	337.0	357.6	394.8	480.9	345.8	337.5
(1968–69 = 100)	(104.0)	(110.4)	(121.9)	(148.6)	(106.8)	(104.2)
Soybean area in ha. (or tons)[a]						
Region 4	7,280	145,600	436,800	1,820,000	4,909	16,820
Region 5	4,190	83,800	251,400	1,047,000	5,122	17,077
Region 6	2,610	52,300	156,900	653,000	2,935	8,827
Region 7	5,920	118,300	354,900	1,480,000	11,254	532
All-India	20,000	400,000	1,200,000	5,000,000	24,220	43,256

Sources: Rathod and Motiramani 1974; Government of India.
[a] Assuming yields are 1 ton/ha.

crease in the rates for soymeal and in making soybean processing feasible also in non-producing regions such as region 2.[14]

Without entering into further discussion of the many reasons why or why not reality differs from the model results in some cases, it can be concluded from the evidence gathered so far over the short period of three years that the soybean economy in India appears to be generally allocating plant capacities and sizes in line with the optimality criteria developed in the model. It should be mentioned here that for several years plans existed to establish one single government-operated processing plant with an initial capacity of about 100 tons per day and a provision to later step up the capacity. This plant was planned to be located in Faridabad, south of New Delhi (Rathod and Motiramani 1974). If only one plant had been available to process the quantities of model years A and B so that interregional trade would have been forced to move soybeans to Faridabad and if soyoil and soymeal were distributed among regions according to the quantities demanded in model years A and B, then this arbitrary solution would have cost the soybean economy in year A about 130% and in year B about 186% of the costs for the optimum solutions (see table 4).

It should be emphasized that starting a soybean economy in India imposes the "chicken-and-egg" problem of simultaneously developing raw material production and processing facilities. If left to itself, this problem will probably be solved by an industry that especially in the initial stages is expanding at very low rates and at the costs of likely mistakes resulting from trial and error approaches. However, with the help of a tool such as the above, despite its many limitations some of the major principles involved in the spatial allocation of the soybean processing industry are recognized and can be applied for future planning by both public and private decision makers in order to foster the growth of the soybean industry.

[14] The ratio of the sum of the costs of transporting soymeal and soyoil over the sum of the costs of transporting soybeans increased from 0.52 in 1970–71 to 0.75 after 1973.

Table 3. Theoretical Optima of Number, Average Capacity, and Average Radius of Market Area of Soybean Processing Plants in Four Model Years

	Region				
Model Year	4	5	6	7	All-India
	Number of Processing Plants[a]				
A	0.5	0.3	0.2	0.4	1.4
B	3.8	1.9	1.2	2.4	9.3
C	7.7	3.7	2.3	4.7	18.4
D	19.3	9.5	5.9	12.0	46.7
	Average Capacity (tons/day)				
A	47	45	47	51	48
B	127	147	145	163	143
C	189	224	224	250	217
D	314	368	370	413	357
	Average Radius (km.)				
A	507	531	504	471	—
B	187	215	197	189	—
C	132	153	141	135	—
D	83	96	89	85	—

[a] The fractional numbers presented here as theoretical optima should for practical purposes be rounded upward, such as to give "recommended" numbers.

Table 4. Comparison between the Costs of Processing and Transportation of the Optimal Solution and of an Arbitrary Solution

Costs[a]	Optimum Solution (million rupees)		Arbitrary Solution (million rupees)		Optimum Solution Divided by Arbitrary Solution	
	Year A	Year B	Year A	Year B	Year A	Year B
Processing cost	2.64[b]	27.85[c]	1.60[d]	23.80[e]	0.61	0.85
Transportation cost of interregional trade	0.14	7.46	2.04	42.13	14.10	5.60
Total cost	2.78	35.31	3.64	65.93	1.30	1.86

[a] Based on 1970–71 processing costs (von Oppen 1972) and rail rates (Indian Railway Conference Association).
[b] Assuming one plant in each production region with capacities as indicated: region 4: 25 tons/day, region 5: 15 tons/day; region 6: 10 tons/day; and region 7: 20 tons/day, i.e., in total, 70 tons/day.
[c] Assuming average processing costs as indicated in table 4.
[d] Assuming one plant with a capacity of 70 tons/day.
[e] Assuming one plant with a capacity of 1,333 tons/day.

Conclusion

With the aim to contribute to the integration of location theory and of interregional trade theory, a model for plant location and interregional trade was developed. Application of the model on data relevant to a projected soybean industry in India produced feasible results. There is evidence that the actual development in the soybean processing sector up to 1974 has followed the earlier projected path fairly closely. It can be shown that an arbitrary plan of processing soybeans in one single plant located in a consumption region would raise costs to the industry 30% above the optimum level for 1970–71 and 86% above the optimum level in 1978–79. Application of the spatial equilibrium model for plant location and interregional trade may help decision makers to recognize the principles involved in the spatial allocation of agriculture-based processing industry and thereby reduce costs and time required for its development.

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Impact of Dryeration on Grain Elevator Performance in a Fluctuating Energy Situation

John B. Penson, Jr., and Bruce A. McCarl

The dryeration process was originally advanced by agricultural engineers to improve grain quality by reducing stress cracks to the kernel normally incurred in the conventional drying process. This study demonstrates that the country grain elevator with dryeration facilities also uses substantially less energy to dry the same amount of grain and achieves higher profits above variable costs associated with drying operations than the elevator with conventional drying facilities, regardless of grain moisture conditions. These advantages are shown to be further magnified if energy prices continue to rise or if potential energy shortfalls are realized.

Key words: elevator profits, energy savings, price rationing, quantity rationing.

The drying function performed by country elevators is a particularly vital service provided to the production and distribution sectors of the nation's food and fiber system. Because this drying function requires large amounts of energy, any disruption to elevator energy supply can in turn result in major disruptions to the remainder of the food and fiber system. Similarly, a significant upward shift in the price of energy may force elevator management to either lower the price they pay for grain or accept lower returns on their investment.

Many experts have raised the spectre of major energy shortfalls in the near future. The U.S. Geological Survey, for example, recently cut by more than one-half their earlier estimates of undiscovered recoverable petroleum and gas reserves in the United States. President Ford, in his 1975 State of the Union Message, advocated raising the domestic price of energy to discourage consumption and encourage domestic production by imposing an import tax on foreign oil and decontrolling domestic "old" oil prices. The individual grain elevator facing either energy shortages or price increases must be prepared to implement energy conserving management strategies that allow for continued receipt and processing of desired grain throughout. One particular management strategy that appears to conserve considerable energy, thereby increasing profits, is the installation of dryeration facilities in the elevator's configuration.

The purpose of this paper is to examine the potential savings to a country grain elevator from adopting dryeration facilities rather than conventional drying facilities. To accomplish this, operations of two alternative elevator configurations that utilize different drying facilities are simulated in accordance with an experimental design. Functions explaining the amount of energy use associated with the quantity of grain dried for each alternative drying facility are then estimated based on these experiments. Finally, a decision model reflecting elevator management behavior under alternative market situations is used to illustrate potential elevator response to selected energy situations.

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Alternative Elevator Configurations

A dynamic simulation model of a typical midwest grain elevator developed and validated originally by Deason was used in this study to

simulate elevator receiving and processing operations over time in a weather-dependent environment. This model was recently modified and updated by Uhrig and McCarl. Figure 1 presents a flow chart that depicts the overall structure of the simulation model and the information it provides.

Monte Carlo methods, using direct transformation of uniform random deviates, are used in the model to obtain values for such stochastic elements as load size, moisture content, and daily arrival pattern. The elevator's performance is dependent upon its designed capacity, the length of the harvest season, its location, weather conditions, and the nature of its drying facility. Once these elements are specified, the simulation model determines daily arrivals and drying schedules using the "first-in–first-out" principle for processing grain receipts.[1]

Two experiments were conducted with this simulation model to determine an elevator's grain drying response surface under alternative elevator configurations. The first experiment focused on the response surface for an elevator using conventional drying facilities, while the second experiment focused on an elevator's response surface when dryeration facilities are adopted. The simulation model was programmed to report the amount of grain dried for every 2,500 gallons of liquid propane equivalent used for each elevator configuration.

Conventional Drying Facilities

Conventional drying facilities, as defined in this study, require grain to be dried to the final desired moisture content and cooled in the dryer. The overall elevator configuration includes wet aerated storage facilities to level out the receipts pattern, thereby allowing the dryer to operate during hours of no receipts. For the purposes of this study, this experiment is designed to reflect two annual elevator capacities: 1.0 and 1.5 million bushels, respectively. The harvest season is assumed to be forty-five days long and the location examined is central Indiana. Weather variability is based upon five years of data from the U.S. Weather Bureau covering the 1959–63 period. The elevator is designed to have a dryer capable of removing five points of moisture from 2,500 bushels per hour and is supported by 20,000 bushels of temporary storage and 100,000 bushels of wet aerated storage. Finally, the elevator is designed to have a 600 bushel dump pit and a 7,000 bushel per hour leg. The mean load size, a stochastic element in the simula-

[1] The grain elevator simulation model developed by Deason was specifically designed to reflect the physical operation of a country grain elevator. As such, the model, which was exhaustively validated, is ideally suited to examining the effects of alternative elevator configurations on physical throughput. For additional description of the properties and validation of the simulation model, see Deason or Uhrig and McCarl.

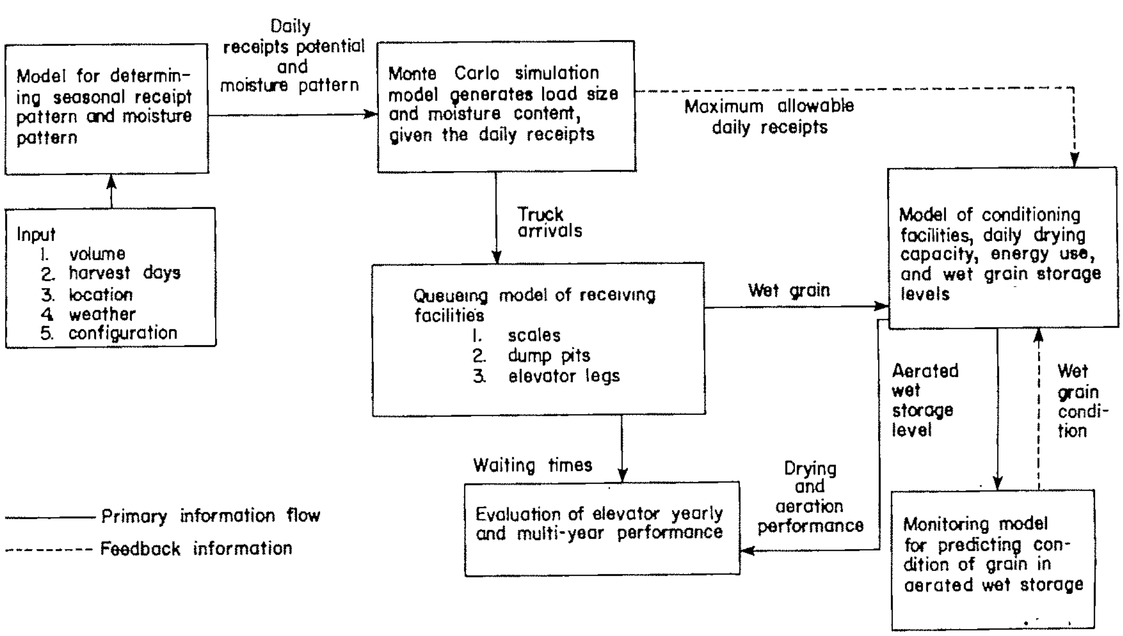

Figure 1. Structure of elevator model and informational flow (adapted from Uhrig and McCarl)

tion model, was 21,000 pounds and was normally distributed with a standard deviation of 6,000 pounds.[2] The mean scale service time was 1.8 minutes and was also normally distributed with a standard deviation of 0.25 minutes.

Each of the trials within the experimental design was simulated under the above conditions for a five-year period. This procedure was then repeated for two additional sequences of random numbers to test the hypothesis that there was a significant difference in the grain drying response surfaces exhibited by each of the three random samples. The results of this experiment are examined in the next section of this paper.

Dryeration Facilities

The above experiment was repeated for an elevator configuration that utilized dryeration rather than conventional drying facilities. Dryeration, as reported by McKenzie et al., involves a regular high speed, high temperature drying facility with a slow cooling process. Unlike conventional drying facilities, no cooling is done in the dryer. Rather, grain is discharged from the dryer while it is still hot and still carrying excess moisture (one to three points above the final desired moisture content) and is loaded into an aerated cooling bin. The grain is stored without aeration for anywhere from four to ten hours for tempering. Finally, the grain is cooled slowly by moving air upward through the bin. The first grain put in the cooling bin will be the first cooled. This slow cooling stage takes approximately ten hours, requires very little energy, and reduces the moisture content about two points. The grain is then unloaded, cool and dry.

Dryeration, according to McKenzie et al. as well as the Council for Agricultural Science and Technology (CAST), not only reduces the occurrence of stress cracks to the kernel normally associated with conventional drying facilities but increases dryer output by 60% for ten points of moisture removed. Furthermore, they suggest that dryeration increases fuel efficiency by 20% to 30% over conventional drying facilities. The impact of the installation of dryeration facilities was accounted for in the simulation model by adjusting the elevator's dryer capacity accordingly.[3]

Determinants of Energy Needs

The following functional form was estimated for each elevator configuration based upon the response surfaces reported by the simulator for each of the above experiments:

$$(1)\quad EU_i = B_{oi} + B_{ei}GR_i + B_{zi}GR_i[Dez] + B_{mi}GR_i[Dhm] + B_{xi}GR_i[Dez][Dhm] + u_i, (i = d, cd),$$

where EU_i = gallons of liquid propane equivalent used to dry grain associated with the ith elevator configuration, GR_i = bushels of grain dried associated with the ith elevator configuration, Dez = 0, 1 dummy variable for alternative annual elevator capacities (1.0 and 1.5 million bushels), Dhm = 0, 1 dummy variable for high moisture conditions (field moisture content greater than 20% at harvest), u_i = random error term associated with the ith configuration, d = elevator configuration with dryeration facilities, cd = elevator configuration with conventional drying facilities.

In both instances, one would expect a positive sign on the B_{ei} coefficient since increases in the quantity of grain dried will require additional energy use. The sign on the B_{zi} coefficient should be negative if elevators become more efficient in their energy use as elevator size increases, other things being constant. The sign on the B_{mi} coefficient is expected to be positive since more moisture removal will necessitate a longer drying time and thereby increase the elevator's energy use for a given amount of grain throughput. The final coefficient, B_{xi}, which reflects the interaction between elevator size and grain moisture, should be negative if the increase in

[2] The hypotheses that load size and moisture content are normally distributed were accepted by Deason based upon the Kolmogorov-Smirnov test for goodness of fit.

[3] Dryer capacity for conventional drying facilities, according to Klein, McCarl, and Peart, is given by

$$DC_{cd} = D_{cd}/[-2.35 + 0.169M_{cd}],$$

where DC_{cd} = conventional dryer capacity, C_{cd} = the bushel per hour capacity of the dryer for five points of moisture removal, and M_{cd} = the moisture content of the grain. For dryeration facilities, dryer capacity is given by

$$\begin{aligned} DC_d = DC_{cd}[1.0 + [[M_d/(100 - M_d)] \\ - [M_{cd}/(100 - M_{cd})]]100]/[[WM/(100 - WM)] \\ - [M_{cd}/(100/M_{cd})]]100, \end{aligned}$$

where WM = the net basis moisture content of grain dried. If M_d = 17.5, M_{cd} = 15.5, and WM = 21.0, the dryer capacity would increase by 34.8% if dryeration facilities were adopted.

energy use under higher moisture conditions declines as plant size increases.

The functional form outlined in equation (1) was estimated for each experiment using ordinary least squares regression. A total of 297 observations were available to estimate the equation for regular drying facilities, while 169 observations were available to estimate the equation for dryeration facilities. This difference in sample size was due to the fact that the elevator with dryeration facilities used less fuel in reaching its maximum grain throughput than the elevator with regular drying facilities.

Equations (2) and (3) below present the results from the estimation of the coefficients of a modified specification of the functional form given in equation (1). Earlier tests show that the B_{zi} and B_{xi} coefficients in equation (1) were not significantly different from 0 at the 10% level:

$$(2) \quad EU_{cd} = 0.01266 + \underset{(0.0023)}{0.0432}\, GR_{cd} + \underset{(0.0022)}{0.0567}\, GR_{cd}[Dhm],$$

and

$$(3) \quad EU_{d} = 0.0085 + \underset{(0.0039)}{0.0393}\, GR_{d} + \underset{(0.0036)}{0.0339}\, GR_{d}[Dhm].$$

The figures in parentheses are standard errors. The coefficient of determination adjusted for degrees of freedom associated with equations (2) and (3) were 0.893 and 0.924, respectively.[4] In both instances, the signs on the b_{ei} and b_{mi} coefficients confirm our earlier hypotheses.[5] In addition, both sets of coefficients were significantly different from 0 at the 1% level. Finally, the b_{ecd} and b_{mcd} coefficients were significantly different from the b_{ed} and b_{md} coefficients, respectively, at the 1% level.[6]

The b_{ei} and b_{mi} coefficients corresponding to the GR_i regressor indicate that an increase in grain drying will require larger amounts of liquid petroleum equivalent for those elevators with conventional drying facilities than for those with dryeration facilities. The reciprocals of the b_{ei} and b_{mi} coefficients in equations (2) and (3) express the effect that an additional gallon of liquid petroleum equivalent can have on the quantity of grain dried, other things being equal. Under low grain moisture conditions (field moisture less than 20%), for example, one gallon of liquid petroleum equivalent was estimated to dry 23.1 bushels of grain at an elevator with conventional drying facilities versus 25.5 bushels at an elevator with conventional dryeration facilities. The b_{ei} and b_{mi} coefficients together indicate that, under higher grain moisture conditions (field moisture greater than 20%), the elevator with conventional drying facilities will dry 11.0 bushels of grain per gallon of liquid petroleum equivalent versus 13.7 bushels if the elevator configuration instead utilizes dryeration facilities. Thus, the elevator with dryeration facilities can dry 10% more grain per gallon of liquid propane equivalent under low grain moisture conditions than the elevator with conventional drying facilities.[7]

Based upon the above empirical results, an analysis of the impact that energy shortages or quantity rationing of energy can have on the performance of a country grain elevator is seemingly straightforward. The quantity of grain dried under alternative grain moisture conditions and energy use levels for elevators with and without dryeration facilities was determined above by expressing equations (2) and (3) in terms of the quantity of grain dried. Yet Federal Energy Administration allocation rules at the time of the Arab oil embargo and those that remain in abeyance at present suggest that the food and fiber system would have top priority in any quantity rationing scheme. Instead, price rationing seems equally, if not more, likely. To determine the potential effect that price rationing can have on the performance and profits of an elevator with or without dryeration facilities, we must propose a model that reflects potential elevator management behavior.

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[4] Earlier tests showed that a double log transformation of equation (1) led to a slightly lower coefficient of determination for each elevator configuration than that reported for equations (2) and (3).

[5] The estimated values for the B_j coefficients (j = 0, 3, and m) are hereafter referred to as b_j coefficients to distinguish between the population parameters and the OLS parameter estimates.

[6] A comparison with estimates based on repeated random samples suggests that we not accept the hypothesis that there is a significant difference in the response surfaces implied by different random samples. The estimates of bushels of grain dried per gallon of energy use are based on grain moisture at harvest during the 1959–63 period in central Indiana. The pounds of water removed and hence amount of energy required are influenced by these moisture levels. Weather data for other time periods may slightly alter the regression estimates.

[7] The CAST suggest that dryeration decreases fuel needs by 20% to 30%. Since corn is typically harvested in the midwest at a moisture content substantially higher than 20%, the 25% increase in fuel efficiency found under high moisture conditions in this study seems reasonable.

Elevator Decision Model

The following model reflects the decision-making framework of elevator management that must pay the farm firm a price for grain (PP_g) that is an increasing function of the quantity it purchases. We shall assume that elevator management is a price taker in its other factor markets and its product market. This assumption permits us to treat the price paid for energy (PP_e), elevator handling costs (HC_i), and the price received for processed grain (PR_g) as given. We shall assume for the purposes of this study that the objective of elevator management is to maximize profits. If PP_g is an increasing function of grain purchases, the elevator will desire to buy grain until the marginal cost of grain purchases equals its marginal revenue product:[8]

$$(4) \quad \max \pi_i = [PR_g - HC_i]GR_i - PP_gGR_i - PP_eEU_i,$$

where

$$(5) \qquad EU_i = b_{oi} + \Phi_{ei}GR_i$$

and

$$(6) \qquad \Phi_{ei} = b_{ei} + b_{mi}[Dhm],$$

subject to

$$(7) \qquad 0 \leq GR_i \leq \theta_{gr},$$

$$(8) \qquad b_{oi} \leq EU_i \leq \theta_{eu},$$

and

$$(9) \qquad PP_g = \delta + \alpha GR^*_i,$$

and where π_i = profit associated with the ith elevator configuration, PR_g = price received by the elevator for grain marketings, PP_g = price paid by the elevator for grain purchases, HC_i = handling costs per bushel excluding drying associated with the ith elevator configuration, b_j = estimated values for the B_j coefficients in equation (1) where $j = o, e,$ and m, PP_e = price paid by the elevator for liquid petroleum equivalent, θ_{gr} = maximum elevator grain throughput, θ_{eu} = maximum liquid petroleum equivalent available to the elevator, and GR^*_i = quantity of grain supplied by the farm firm to the ith elevator configuration.

Equation (5) represents a restatement of equations (2) and (3) for an elevator with and without dryeration facilities, respectively. Equations (7) and (8) account for annual elevator capacity and energy availability constraints. Equation (9) reflects the farm firm's response to the purchase price of grain (PP_g), where price rather than quantity is used as the dependent variable. GR^*_i represents grain sales by the farm firm, while $\alpha\,[GR^*_i/PP_g]$ is the measure of price flexibility.

Two simplifying assumptions are made with respect to the model above. First, we assume that the elevator can get all the energy it needs at price PP_e. This assumption renders the constraint in equation (8) ineffective. Our second assumption is that we can neglect the elevator capacity constraint in equation (7) for the moment. Given these assumptions, we can solve for the equilibrium condition. By substituting equations (5) and (9) into equation (4) and differentiating with respect to GR_i, we see that

$$(10) \quad \frac{d\pi_i}{dGR_i} = PR_g - HC_i - PP_e\Phi_{ei} - [\delta + 2\alpha GR_i),$$

where

$$(11) \qquad \frac{d^2\pi_i}{d\,GR_i^2} = -2\alpha.$$

The last term in equation (10) represents the marginal cost of grain purchases to the elevator. Where equation (10) is equal to 0 and equation (11) is less than 0 (i.e., α is positive), elevator profits are at their maximum.

We can now set equation (10) equal to 0 and solve for the desired level of grain dried. This quantity, expressed in millions of bushels, is given by

$$(12) \quad GR_i = \left[\frac{PR_g - HC_i - \delta - PP_e\Phi_{ei}}{2\alpha}\right],$$

where $0 \leq GR_i \leq \theta_{gr}$. By substituting the value for GR_i obtained from equation (12) into equations (5) and (9), we can determine the desired level of energy use and the price paid for grain, respectively. Finally, elevator profits above variable costs associated with drying activities are determined by substituting the values for GR_i, EU_i, and PP_g into equation (4).

In order to complete the model, we must determine values for δ and α in equation (9). We shall examine the effect that two hypothesized input supply elasticities that reflect al-

[8] In the event that there are many elevators serving the local grain purchase market, the individual elevator will instead maximize producer plus consumer surplus. By integrating under the curves and solving for GR_i, it can be shown that the denominator in equation (12) would equal α rather than 2α. Solutions of the model under these conditions show that the elevator with dryeration facilities has a competitive advantage; it can pay more for grain and stand a much higher price for energy regardless of level of grain moisture.

ternative assumptions regarding the degree of competition the elevator faces in the grain purchase market has on its performance and profits. The first elasticity is one that approaches infinity ($\xi_p \to \infty$), reflecting the micro "perfect competition" assumption that an elevator has little or no influence on PP_g. The second elasticity of 5.0 allows for more elevator influence on PP_g.[9]

The model accounts for the performance and profits of a country grain elevator when the price of energy is exogenously altered. In the case where the supply of energy to the country grain elevator is limited due to, say, quantity rationing (i.e., $EU_i = \theta_{eu}$), other things being constant, the quantity of grain dried will be given instead by

$$GR_i = 1/\Phi_{ei}[-b_{oi} + \theta_{eu}], \tag{13}$$

where $0 \leq GR_i \leq \theta_{gr}$.

By assuming values for PR_g, PP_e, and HC_i, we can now use the elevator decision model to illustrate the potential magnitude of an elevator's response to selected energy situations for elevator configurations with and without dryeration facilities.

Potential Savings from Dryeration

Table 1 presents the desired quantities of energy use and grain dried for a country grain elevator with and without dryeration facilities for those values of PR_g, PP_e, and HC_i assumed in this study. The model solutions presented reflect the effect of low and high grain moisture conditions for two hypothesized input supply elasticities.

If grain moisture at harvest is less than 20%, there is only a slight economic advantage to elevator management investing in dryeration facilities. Depending on the degree of competition in the grain purchase market, elevator profits above variable costs associated with drying operations will be 1% to 3% higher with dryeration facilities. This increase in profits is a direct result of the 14% to 16% increase in fuel efficiency. It is interesting to note that if the input supply elasticity is 5.0, the elevator with dryeration facilities will actually prefer to dry 0.2% less grain than it would otherwise because of higher handling costs.[10] Further, the value for PR_g would have to reach \$2.80, other things being constant, before either elevator configuration would be operated at full capacity.

If grain moisture at harvest is more than 20%, there is a decided economic advantage to the elevator management that invests in dryeration facilities. Depending again on the degree of competition the elevator faces in the grain purchase market, elevator profits above

[9] When $\xi_p \to \infty$, $\alpha \to 0$, that is, the elevator's marginal cost of purchasing grain $PP_g[1 + (1/\xi_p)] = \$2.25$. The values for α and δ for both elasticities are based upon a price of \$2.25 and a quantity of 1 million bushels.

[10] The operation of dryeration facilities requires an additional handling cost of \$1 per dryer load from running the cooling fan and handling equipment to load and unload the bin. This charge is based on \$0.06 per kilowatt-hour for power and 2,500 bushels of grain dried per day. Thus, a \$0.003 per bushel charge must be added to the handling cost of \$0.08 per bushel incurred with conventional drying facilities. Since the dryeration facilities are fully automated, there is no additional labor charge.

Table 1. Comparison of Optimal Solutions for a One Million Bushel Country Grain Elevator

Item	Dryeration Facilities		Conventional Drying Facilities		Percentage Change from Conventional Drying Facilities[a]	
	$\xi_p = 5.0$	$\xi_p \to \infty$	$\xi_p = 5.0$	$\xi_p \to \infty$	$\xi_p = 5.0$	$\xi_p \to \infty$
			Low Grain Moisture			
GR_i (mil. bu.)	0.663	1.000	0.664	1.000	−0.21	0
EU_i (mil. gal.)	0.035	0.048	0.041	0.056	−16.20	−14.34
PP_g (\$/bu.)	2.098	2.249	2.099	2.249	0	0
π_i (mil. \$)	0.194	0.146	0.193	0.142	0.73	2.82
			High Grain Moisture			
GR_i (mil. bu.)	0.644	1.000	0.633	1.000	1.83	0
EU_i (mil. gal.)	0.056	0.082	0.076	0.113	−26.52	−27.38
PP_g (\$/bu.)	2.090	2.249	2.085	2.249	0.25	0
π_i (mil. \$)	0.183	0.129	0.174	0.114	4.93	13.59

Note: These results are based upon solutions where $PR_g = \$2.50$, $PP_e = \$0.50$, $HC_d = \$0.083$, and $HC_{cd} = \$0.08$ per unit. The values for δ and α in equation (9) for both supply price elasticities examined in this study are based upon a price of \$2.25 paid for grain (PP_g) and a quantity of 1 million bushels supplied.

[a] Computed from unrounded data.

variable costs will be 5% to 14% higher under dryeration. If the elevator with dryeration facilities faces an input supply elasticity of 5.0, it will dry almost 2% more grain and yet use 26.5% less energy. Both elevator configurations would require a value of $2.82 for PR_g before they would choose to operate at full capacity. If, on the other hand, both elevators face an input supply elasticity approaching infinity, the amount of grain dried will be limited by the 1 million bushel annual elevator capacity assumed in this solution. The elevator with dryeration facilities, however, will use 27.4% less fuel to dry the same amount of grain.

Effects of Alternative Energy Solutions

The purpose of this section is to extend further our analysis of the potential savings from the adoption of dryeration facilities by examining the impact that selected quantity and price rationing schemes can have on the performance and profits of a country grain elevator.

Quantity Rationing

Quantity rationing of energy, other things being constant, can have only one of two possible effects: it will be ineffective where the quantity required is less than the quantity rationed (i.e., $EU_t < \theta_{eu}$), or it will limit the elevator's performance and profits (i.e., $EU_t = \theta_{eu}$). We shall assume that quantity rationing of energy to a country grain elevator is a feasible policy alternative and that the elevator was previously operating at the point where profits above variable costs were maximized (see table 1). Alternative solutions of the elevator decision model in which previous energy use associated with drying operations is reduced by 10% and 20%, respectively, are shown in table 2.

A comparison of tables 1 and 2 shows that an elevator facing an input supply elasticity approaching infinity under high grain moisture conditions will suffer a 10% to 12% loss in profits above variable costs if the amount of energy previously used to dry grain is reduced by 10%. If energy supplies are instead reduced

Table 2. Effect of Reductions in the Supply of Liquid Propane Equivalent on a One Million Bushel Capacity Elevator

Item	Dryeration Facilities		Conventional Drying Facilities	
	$\xi_p = 5.0$	$\xi_p \to \infty$	$\xi_p = 5.0$	$\xi_p \to \infty$
Effect of a 10% reduction of EU on		Low Grain Moisture		
GR_t (mil. bu.)	0.598	0.899	0.598	0.899
EU_t (mil. gal.)	0.037	0.044	0.038	0.051
PP_g ($/bu.)	2.069	2.249	2.069	2.249
π_t (mil. $)	0.192	0.128	0.190	0.127
		High Grain Moisture		
GR_t (mil. bu.)	0.580	0.899	0.569	0.899
EU_t (mil. gal.)	0.051	0.074	0.069	0.103
PP_g ($/bu.)	2.061	2.249	2.056	2.249
π_t (mil. $)	0.181	0.113	0.172	0.102
Effect of a 20% reduction of EU on		Low Grain Moisture		
GR_t (mil. bu.)	0.531	0.799	0.531	0.799
EU_t (mil. gal.)	0.029	0.040	0.036	0.047
PP_g ($/bu.)	2.039	2.249	2.039	2.249
π_t (mil. $)	0.186	0.114	0.185	0.112
		High Grain Moisture		
GR_t (mil. bu.)	0.516	0.799	0.506	0.799
EU_t (mil. gal.)	0.046	0.067	0.063	0.093
PP_g ($/bu.)	2.032	2.249	2.028	2.249
π_t (mil. $)	0.176	0.100	0.167	0.090

by 20%, elevator profits would decline by 21% to 23%. In both instances, profits above variable costs for an elevator with dryeration facilities would decline by a greater percentage but would still be higher than profits of an elevator with conventional drying facilities. The quantity of grain dried by both elevators would fall by about the same percentage that energy is rationed.

If the elevator under high grain moisture conditions instead faces an input supply elasticity of 5.0, it will pay 1.4% less for grain if the 10% quantity rationing scheme is employed and 2.8% less if the 20% scheme is used. Because of these lower values for PP_g, profits of an elevator with dryeration facilities would now decline by a smaller percentage than profits of an elevator with conventional drying facilities. While the quantity of grain dried still falls by about the same percentage that energy is rationed, it is interesting to note that an elevator with either drying facility in a year of high grain moisture would operate at one-half capacity if energy supply is cut by 20%.

Price Rationing

Unlike the quantity rationing schemes, we shall now assume that the elevator can get all the energy it needs at a value for PP_e determined by a price rationing scheme. Two such price rationing schemes are examined here for their effect on elevator performance and profits. Alternative solutions of the elevator decision model in which the previous value for PP_e of \$0.50 including tax is increased by \$0.25 and \$0.50, respectively, are presented in table 3.

A comparison of tables 1 and 3 shows that an elevator with dryeration facilities operating under high grain moisture conditions and facing an input supply elasticity approaching infinity would suffer a 15.5% loss in profits above variable costs if PP_e was increased to \$0.75. The profits of an elevator under the same moisture conditions with conventional drying facilities would decline by 24.6%. If PP_e were instead increased to \$1, the elevator under the above conditions with dryeration facilities would see its profits above variable

Table 3. Effect of Increases in the Price of Liquid Propane Equivalent on a One Million Bushel Capacity Elevator

	Dryeration Facilities		Conventional Drying Facilities	
Item	$\xi = 5.0$	$\xi \to \infty$	$\xi = 5.0$	$\xi \to \infty$
Effect of a \$0.25 increase in PP_e on		Low Grain Moisture		
GR_t (mil. bu.)	0.652	1.000	0.652	1.000
EU_t (mil. gal.)	0.034	0.048	0.041	0.056
PP_g (\$/bu.)	2.093	2.249	2.093	2.249
π_t (mil. \$)	0.186	0.134	0.182	0.128
		High Grain Moisture		
GR_t (mil. bu.)	0.624	1.000	0.605	1.000
EU_t (mil. gal.)	0.054	0.082	0.073	0.113
PP_g (\$/bu.)	2.081	2.249	2.072	2.249
π_t (mil. \$)	0.169	0.109	0.156	0.086
Effect of a \$0.50 increase in PP_e on		Low Grain Moisture		
GR_t (mil. bu.)	0.641	1.000	0.640	1.000
EU_t (mil. gal.)	0.034	0.048	0.040	0.056
PP_g (\$/bu.)	2.088	2.249	2.088	2.249
π_t (mil. \$)	0.177	0.122	0.172	0.114
		High Grain Moisture		
GR_t (mil. bu.)	0.641	1.000	0.640	1.000
EU_t (mil. gal.)	0.053	0.082	0.070	0.113
PP_g (\$/bu.)	2.071	2.249	2.060	2.249
π_t (mil. \$)	0.156	0.088	0.138	0.058

costs decline by 31.8%, while the elevator with conventional drying facilities would suffer a 49.1% decline. Importantly, the amount of energy used by either configuration in which the input supply elasticity approaches infinity would not change despite the higher values for PP_e.

Although the elevator confronted by an input supply elasticity of 5.0 will experience smaller declines in profits, it will also use less energy and dry less grain. A comparison of tables 1 and 3 indicates that an elevator with dryeration facilities under high grain moisture conditions will reduce its energy consumption by 3.6% when PP_e is increased to \$0.75 and 5.4% when PP_e is increased to \$1. Accordingly, the quantity of grain dried would decline by 3.1% and 6.2%, respectively. If the elevator was instead equipped with conventional drying facilities, its energy use would decline by 4.0% and 7.9% and the quantity of grain dried would decline by 4.4% and 8.9%, respectively.

The Investment Decision

Assuming that the elevator wishes to expand its drying capacity, the choice between dryeration and conventional drying facilities will depend on which has the highest net present value. According to McKenzie et al., the cost of a new dryer is about \$3,000 per 1,000 bushels of daily drying capacity. If dryeration increases the existing dryer's capacity by 60%, a 1,600 bushel dryer coupled with dryeration equipment could handle an additional 1,000 bushels per day. Thus, we want to compare the cost of the dryeration equipment capable of handling a 1,600 bushel dryer to the \$3,000 cost of the new dryer.

The primary cost of converting to dryeration is the investment in a cooling bin, aeration equipment, and additional grain handling equipment to fully automate the facility. A dryer with a 1,600 daily capacity will require a cooling bin large enough to handle a minimum of 2,500 bushels per day to accommodate the 60% increase in dryer capacity. According to McKenzie et al., the cost of a cooling bin runs about \$1 per bushel, while the capital equipment needed to complete the facility costs about \$1,000. Thus, the initial investment cost for the dryeration facilities would be roughly \$500 higher than conventional drying facilities.[11] Ranking of these two investment alternatives will depend therefore on whether the net present value of elevator profit flows over the service life of dryeration facilities is more than \$500 greater than that for regular drying facilities. This assumes that the length of service life, degree of market risk, and salvage values for both facilities are equal. A review of tables 1, 2, and 3 shows that, based upon the prices assumed in this study, this criterion is easily met in areas in which grain is harvested with a moisture content greater than 20%, regardless of whether either of the rationing schemes examined in this study are implemented. The investment decision in areas where grain is normally harvested at lower grain moisture contents may depend on the degree of competition the elevator faces in the grain purchase market and the cost of energy.

Summary and Conclusions

The purpose of this study was to estimate the potential savings a country grain elevator could realize by investing in dryeration facilities. The solutions to the elevator decision model indicate that dryeration leads to higher profit levels over variable costs and a more efficient use of energy than conventional drying facilities, particularly if grain is harvested at a relatively high moisture content. This economic advantage is further magnified if either price or quantity rationing schemes are implemented. In addition to these advantages, there remains the purpose for which dryeration facilities were originally advanced: they reduce the amount of stress cracks to the kernel, thereby increasing corn quality. The recognition of this feature of dryeration in our grading standards for feed grains would result in even higher profit levels above variable costs for the elevator equipped with dryeration facilities and promote a more efficient use of our energy supplies.

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[11] If season-end storage capacity is needed, whether dryeration is used or not, then most of the cooling bin cost can be considered as storage cost rather than dryeration facility cost.

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A Sequential Model of the Farm Firm Growth Process

Ying I. Chien and Garnett L. Bradford

Multiperiod linear programming and computer simulation techniques are integrated into a single recursive-sequential model of the farm firm growth process. The model is tied to dynamic theories of the firm's planning behavior first developed by Hicks and more recently by Modigliani and Cohen. A central Kentucky beef farm empirically illustrates predictive features of the model. Three alternative beef production management strategies are compared to demonstrate the model's potential for explaining and predicting alternative farm firm growth processes.

Key words: beef, computer simulation, farm firm growth, linear programming.

Most farm firm growth research of the past twenty years has employed either multiperiod linear programming (MLP), recursive linear programming (RLP), or computer simulation (CS).[1] Potential benefits of such models are impressive, but when used alone each contains shortcomings inherent in the assumptions. The typical MLP model provides a global optimal solution and has other dynamic features but assumes certain knowledge about production and price coefficients and that all inputs and products are perfectly divisible. As demonstrated in previous studies (Martin and Plaxico; Johnson, Tefertiller, and Moore), these assumptions can be relaxed to a limited extent. Johnson, Tefertiller, and Moore, for example, relaxed the certainty assumption by using a Monte-Carlo method to allow variation in yields of crop activities. Heidhues, using an RLP model, was among the first to develop a sequential optimizing procedure to describe how plans for a given time period are related to past entrepreneurial expectations and performances of past plans. Thus, his model contained predictive as well as prescriptive features.

Neither MLP nor RLP models used alone, however, can adequately handle and predict financial variables. Also, it is difficult to incorporate behavioral and qualitative decision variables into programming models. Computer simulation (CS) models can transcend such difficulties and if properly constructed can handle multiple goals, indivisibilities, and sequential decisions (see Hinman and Hutton, Patrick and Eisgruber). Still, CS models used alone tend to lack optimizing features and adequate linkage among time periods in the overall planning process.

These shortcomings can result in substantial gaps between theory and reality. For these reasons, this article is designed to extend and improve existing firm growth modeling techniques by combining desirable features of the MLP, RLP, and CS models into a single computer-based model. The proposed sequential model is based on theoretical constructs discussed briefly in the next section, followed by an outline of the model framework and an empirical illustration.

Theoretical Constructs

Our conceptual framework of the farm firm growth process rests upon theories developed by Hicks and later by Modigliani and Cohen. When combined, these theories take into account dynamic planning behavior of the firm's management and also take into consideration that the model should be capable of implementing farm planning and operations into a real world setting.

In his *Value and Capital*, Hicks developed a dynamic decision-making theory of the firm

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[1] Irwin's extensive review of the pre-1969 literature (pp. 82–100) is consistent with this classification.

under certainty. According to his view, just as in static theory the firm is to choose from among alternative available courses of action the one that is most conducive to the achievement of its goal. Hicks expressed his idea by arguing that "... the decision which confronts any particular entrepreneur at any date ... may be regarded as the establishment of a production plan ..." (p. 193). He comments further that "... just as the static problem of the entrepreneur is the selection of a certain set of quantities of factors and products, so the dynamic problem is the selection of a certain production plan from the alternatives that are open ..." (p. 194). From this proposition, he concludes that the decision problem faced by the firm at any given point of time is the selection of the best plan over the planning horizon. The most fundamental way of selecting the preferred production plan involving costs and returns in future periods is that of the largest capitalized value from the several streams of surplus. Hicks called it "... their capitalized value of the production plan ..." (p. 195).

The implication of Hicks's formulation is that at the beginning of each period the firm faces an optimization problem, subject to certain constraints over some definite horizon. He also implicitly indicates that definite estimates of parameters associated with these constraints are obtainable through anticipations.

Modigliani and Cohen contend that in reality "economic men" do not generally behave expressly in the way implied by Hicks's concept. They indicate that the discrepancy between the conclusion of Hicks's analysis and observed behavior may be explained in three ways. First, uncertainty is involved in the real world, and the existence of uncertainty tends to shorten considerably the time horizon over which it is useful to form anticipations or to formulate plans. Second, Hicks's model, which assumes rational behavior on the part of business firms, cannot thus adequately account for actual behavior. Finally, they argue "... while it is perfectly true that in terms of the pay-off function the single current move of the static model is replaced by the entire set of moves over the horizon, it does not necessarily follow that, as in the static model, the firm must choose now its entire course of action ..." (p. 20). Therefore, they propose "... the decision problem confronting the entrepreneur at a given point of time is most usefully regarded not as that of selecting the best possible plan of operations over the horizon, but rather, as that of *selecting the best possible first move only*" (p. 20).

The "best possible" not only refers to the first period but refers to the entire optimization problem over the horizon. In this sense, this formulation is similar to Hicks's notion. However, there is a conceptual difference in that their formulation places major stress on the first period of the planning period. It also stresses the point that the decision maker will revise his plans when information becomes available through time, even if he does not have great confidence. Long-run plans are, therefore, not necessarily made up in order to be implemented but mostly to utilize all the available information to make the best plan for the current period.

Overview of the Model

Four recursive phases of farm business planning and implementation comprise the framework of the model (figure 1). Consistent with Hicks's concepts, we argue that at the beginning of each planning horizon the farm firm entrepreneur formulates price and yield expectations in accordance with his goals, the firm's resources, the existing enterprise organization, and financial situation (phase 1). These expectations form a basis for the delineation of an optimal long-run plan (phase 2).

While we accept the essence of Hicks's concept, it is not realistic that any optimum multiperiod plan is likely to be implemented through all periods of the planning horizon. Expectations by definition are *ex ante*, subject to errors. Institutional and political forces are constantly shifting. The entrepreneur continually gains experience and gathers information, even though his psychological inertia tends to inhibit alterations in the plan. Thus, in concert with Modigliani and Cohen, we argue that the entrepreneur formulates a long-run plan primarily to provide for the best possible first move during the current period. Such managerial processes are taken into consideration through the computer simulation submodel, which includes behavioral constraints and the decision-operation process (phase 3).

At the end of each period, the current plan becomes the realized (*ex post*) plan. The farm firm entrepreneur accumulates information regarding the outcome from previous decisions and operations and prepares summary reports.

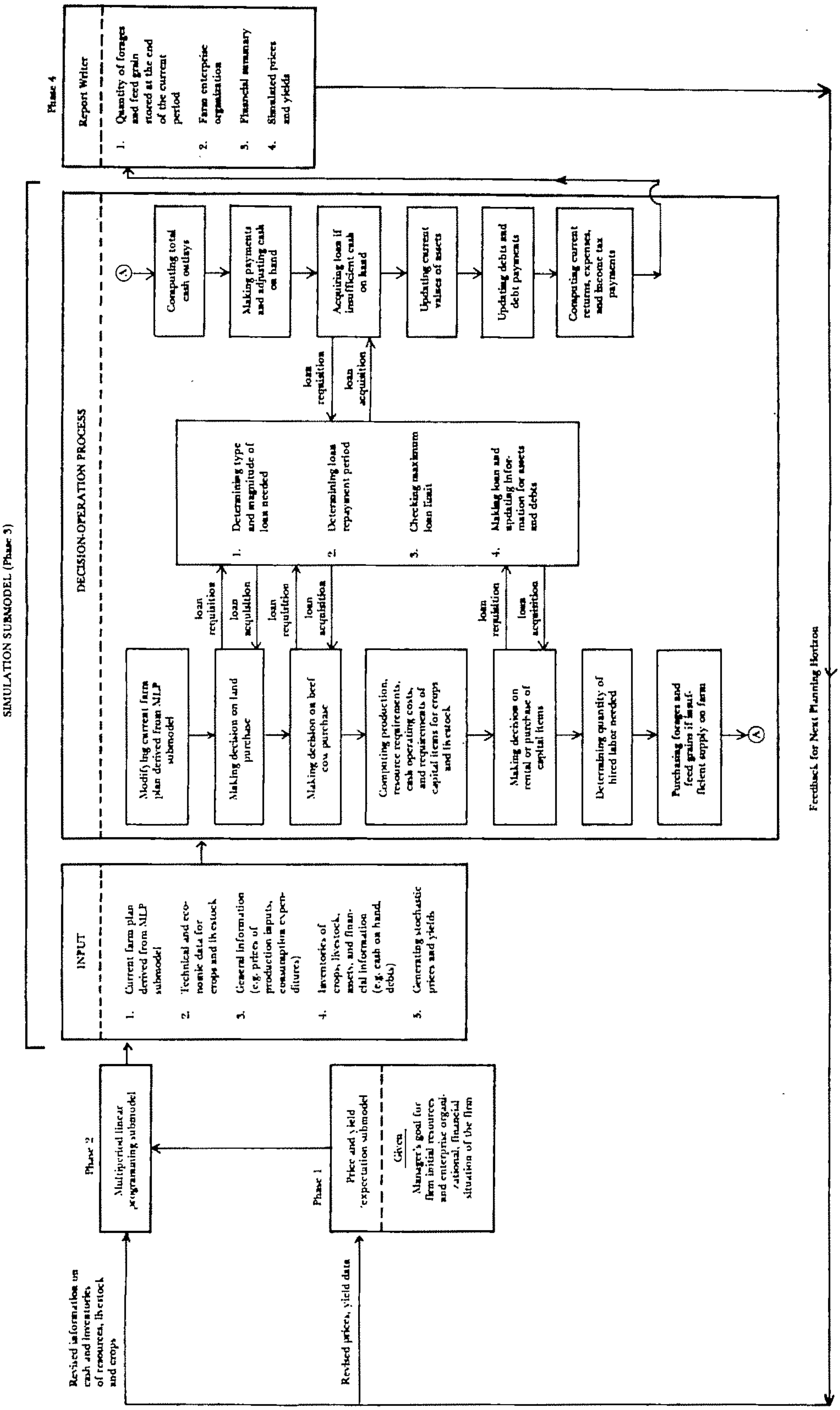

Figure 1. A schematic diagram of the sequential model of the farm firm growth process

With this accumulated (updated) information he then formulates new price and yield expectations and then a new or modified *ex ante* (long-run) plan for the next planning horizon. A time path of this farm firm growth process may be obtained by repeating the sequence of phases over a number of periods.

The Operational Model

The expectation submodel, adapted from Nerlove's distributed lag model (p. 52), is used to quantify the entrepreneur's price and yield expectations (phase 1). Initial expected levels for yields were computed from 1961 to 1965 (USDA). Levels for prices were adapted from Kentucky data (Card and Koepper). Coefficients of expectations were assigned on the basis of "thumb rules" obtained in consultation with agricultural extension specialists for the respective commodities.

The MLP Submodel

Multiperiod linear programming (MLP) is used to approximate the entrepreneur's long-run planning behavior. It is assumed that he will behave as if he made a long-run plan consistent with Hicks's theory underlying the MLP model. Mathematical details of this submodel may be found in Chien and Bradford. A summarized version is

$$\text{(1)}\quad \max \sum_{i=0}^{k} C_{t+i} X_{t+i} \text{ subject to}$$

$$\begin{bmatrix} A_t & & & & \\ & A_{t+1} & & & \\ & & \cdot & & \\ & & & \cdot & \\ & & & \cdot & \\ & & & & A_{t+k} \end{bmatrix} \begin{bmatrix} X_t \\ X_{t+1} \\ \cdot \\ \cdot \\ \cdot \\ X_{t+k} \end{bmatrix} \leq \begin{bmatrix} B_t \\ B_{t+1} \\ \cdot \\ \cdot \\ \cdot \\ B_{t+k} \end{bmatrix},$$

$X_{t+i} \geq 0$, for $i = 0, \ldots, k$,

where C_{t+i} = a row vector of expected net returns or expected expenses of a unit of activities in planning period $t + i$, $i = 0, \ldots, k$;[2] this vector is extended over the planning horizon of $k + 1$ periods; X_{t+i} = a column vector containing alternative activities in the planning period $t + i$, $i = 0, \ldots, k$; A_{t+i} = a matrix that contains input-output and transition coefficients for planning periods $t + i$, $i = 0, \ldots, k$; and B_{t+i} = a vector that contains the amounts of resources available for planning period $t + i$, $i = 0, \ldots, k$.

While the structure of this submodel parallels what has been used in previous studies (e.g., Martin and Plaxico), it possesses a distinct feature in the feedback system to provide information on resource availabilities for each successive planning period.[3] The mathematical expression of the feedback system is

$$\text{(2)}\quad B_t = \Lambda_{t-1} B^*_{t-1} + \Gamma_{t-1} B_{t-1}, \quad \text{for } t = 1, 2, \ldots, T,$$

and

$$\text{(3)}\quad B_{t+i} = \Gamma_{t+i-1} B_{t+i-1}, \text{for } i = 1, 2, \ldots, k,$$

where B_t = the column vector of resource amounts estimated to be used in period t for the right-hand-side vector of the MLP submodel; B_{t-1} = a column vector of resource amounts existing at the end of period $t - 1$; B^*_{t-1} = a column vector of resource amounts purchased in the previous period, $t - 1$; Γ_{t-1} = a diagonal matrix containing straight-line depreciation rates for existing inputs, except those purchased in period $t - 1$; the rate of depreciation for nondurable inputs is 1; Λ_{t-1} = a diagonal matrix containing straight-line depreciation rates for inputs purchased in period $t - 1$; and B_{t+1} = a column subvector of resource amounts to be used in successive periods after period t. Equation (3) accounts for resource depreciation that occurs in subsequent periods $t + i$. Depreciation rates in the matrix Γ_{t+i-1} may differ among periods.

Three steps are required to obtain the solution of equations (2) and (3). First, initial resource conditions (i.e., the vector B_0) must be analyzed. Second, the quantity of durable inputs purchased in the preceding period(s) must be determined. Third, depreciation for the durable inputs must be computed. The latter two steps are handled by the simulation submodel.

The Monoperiod Simulation Submodel

The simulation submodel (figure 1) is similar in many ways to models used by Hutton, Hinman and Hutton, and Patrick and Eisgruber. The simulation input data include the current farm plan derived from the MLP submodel, technical and economic data for crops and livestock, prices of inputs, consumption ex-

[2] The subscripts i and k refer to the individual period and the planning horizon, respectively.

[3] Boehlje and White's MLP model readdressed the enterprise choice question each production period. The model of this article performs this same function, i.e., a feedback of new resource levels through the simulator (phase 3).

penditures, inventories of crops and livestock, assets and other financial information, and a stochastic price and yield-generating scheme.

A random number generator (IBM Corporation) is used in conjunction with an exponential smoothing technique (Brown and Meyer, pp. 673–87) to estimate yields and prices of crops and livestock. The procedures are outlined in equations (4) through (7):

$$(4)\qquad S_{j,t}(Y) = \theta Y_{j,t-1} + (1 - \theta)S_{j,t-1}(Y),$$

where $S_{j,t}(Y)$ = the smoothed value for variable Y (yield for crop j or price for product j) in time period t, $Y_{j,t-1}$ = the actual or model-generated yield for crop j or price for product j in time period $t - 1$, and θ = the smoothing constant. $0 \leq \theta \leq 1$.

Initial smoothing values ($S_{j,0}$) and the smoothing constant (θ) were estimated from pre-1967 time-series data (Kentucky Crop and Livestock Reporting Service). The "best" estimate of the smoothing constant ($\hat{\theta}$) is considered to be the one that minimizes the sum of squares of the forecast errors.

In order to correct equation (4) for lag behind any systematic trend in the data, differences between successive smoothed values are used as estimates of trend. Again, exponential smoothing is used on successive differences to compute an average trend. Successive differences are expressed as

$$(5)\qquad C_{j,t}(Y) = S_{j,t}(Y) - S_{j,t-1}(Y),$$

where $C_{j,t}(Y)$ = the change in the smoothed value for variable Y (yield for crop j or price for product j) between periods t and $t - 1$, and $S_{j,t}(Y)$ and $S_{j,t-1}(Y)$ are defined in expression (4).

The smoothed trend ($T_{j,t}(Y)$) is computed by a linear combination of $C_{j,t}(Y)$ and the estimated yield (price) trend ($T_{j,t-1}(Y)$) for time period $t - 1$, i.e.,

$$(6)\qquad T_{j,t}(Y) = (1 - \phi)\, C_{j,t}(Y) + \phi T_{j,t-1}(Y),$$

where ϕ = the trend smoothing constant, $0 \leq \phi \leq 1$.

Finally, the simulated yield or price for a particular product is generated using the following equation and the IBM subroutine for random number generation:

$$(7)\qquad Y_{j,t} = S_{j,t}(Y) + T_{j,t}(Y) + \epsilon_{j,t},$$

where $Y_{j,t}$ = the actual or model-generated yield (or price) in period t, and $\epsilon_{j,t}$ = a stochastic variate affecting the yield or price for product Y, assumed to be distributed $N(0, \sigma^2)$.

After receiving input data the simulator begins executing the decision-operation process for the current farm plan. Recognizing that factors such as lumpiness of durable inputs, uncertainty, and psychological inertia may prohibit the entrepreneur from carrying out the optimal plans as prescribed by the MLP model, the technique of behavioral constraints (Henderson, pp. 242–66) is used through the simulator to take account of such phenomena. Level bounds for enterprises in any given period are specified as

$$(8)\qquad (1 - \beta)\, X_{j,t-1} \leq X_{j,t} \leq (1 + \alpha)\, X_{j,t-1},$$

where $X_{j,t}$ = the level of enterprise j to be produced in period t, $X_{j,t-1}$ = the actual or solution level of enterprise j produced in period $t - 1$, and α and β = maximum allowable percentages of increase and decrease, respectively, from the enterprise level in the previous period(s).

Entering enterprise levels for the current period are determined in the decision-operation process of the simulator by comparing the optimal enterprise levels obtained from MLP with the two bounds.[4] The following decision rules are used: the optimal enterprise level is accepted if it falls within the two bounds, the upper bound is accepted if the optimal level is larger, and the lower bound is accepted if the optimal level is smaller.

Once a modified current farm plan is established, the simulator then implements operations of the plan and executes decisions regarding the additions of production inputs such as land, beef cows, machinery, feeds, etc. Purchase quantities depend on production requirements, resource inventories, and investment decision rules built in the simulator. For example, capital asset purchase or rental decisions are made by the simulator in accordance with two decision rules: (*a*) if during a particular time period the deficiency of a capital input service exceeds its average annual usage by one-third or more, the asset is purchased; otherwise, it is rented;[5] and (*b*) if two or more types of capital assets need to be acquired, the order of purchase depends upon

[4] Upper and lower bounds for each enterprise were estimated from reviews of farm records in the Kentucky Farm Analysis Program, Bluegrass Area, and personal interviews with the farm manager(s). As Sahi and Craddock recently demonstrated, this method is an oversimplification unless the bounds remain relatively unchanged across time. Stability, however, was present for the study applications presented in this article.

[5] This assumes, of course, that sufficient internal funds exist for down-payment or rental costs. If not, the simulator disallows the purchase (rental).

the "degree of necessity" of the items. Necessity rankings assigned to the asset items are subjectively made on the basis of the type of farm business and through personal consultation with the entrepreneur(s). Down-payment percentages are specified on the basis of farm-planning manuals, e.g., Ray and Hudson. Loan requisition and acquisition procedures are processed by the simulator. All debts and repayments are updated and grouped by type of assets and length of the repayment schedule at the end of each period.

Several accounting calculations are included in the simulator—depreciation of capital items, current returns, expenses, income tax payments, a summary of assets, liabilities, and net worth. To estimate family consumption expenditures, a modified version of a consumption function (Trimble, Connor, and Brake) first developed by Brake was adapted for the simulator.

The final portion of the simulator is the report writer (phase 4). It prepares a report for the current period on resource inventories, the farm enterprise organization, a financial summary, and the model-generated prices and yields of the products.

An Empirical Illustration

The model was applied to a tobacco-beef farm located in the Central Bluegrass area of Kentucky, the overriding concern being to illustrate that the model is operational and in concert with the underlying methodological concepts.[6] The application farm's actual enterprise organization and financial positions as of 31 December 1966 and 1970 are shown in table 1. Enterprise alternatives and most of the resource, investment, and borrowing capacity

[6] The application farm was selected by extension specialists prior to model construction or any other phases of this research study. At that time, this farm was believed to be rather typical of central Kentucky beef farms attempting to grow in size. The argument that a representative-type synthesized farm application more thoroughly tests "predictive powers" of a model than a single application farm seems to rest primarily on a single premise, viz., simulated results are in effect compared to an average of actual results rather than one observed set of results. The counter argument—favoring at least initially using a single-case approach—also possesses some degree of validity. First, the farm situation is an actual one. Second, if prior to testing the model the farm is randomly selected from a well-identified population, the single case comparison could have some preferable statistical properties because the variance of an observation (one farm) always exceeds the variance of an average. A representative farm that is constructed from a "good" sample of actual farms obviously would be superior. One that is synthesized from budgets purporting to depict the population may not be.

Table 1. Enterprise Organization and Financial Situation for the Application Farm: 31 Dec. 1966 and 1970 Actual Values

Item	31 Dec. 1966	31 Dec. 1970
Enterprise organization		
Crops[a] (acres)		
Burley tobacco	8.68	8.62
Corn	0	22
Corn silage	10	25
Hay	33	17
Pasture I	249.32	271.38
Pasture II	184	184
Livestock (head)		
Cow calf	71	68
Feeder cattle	62	75
Financial situation		
Assets ($)		
Cash	9,544	2,100
Bonds and other securities	24,500	15,000
Livestock on hand	24,200	43,000
Crops on hand	0	5,000
Machinery[b]	6,900	27,500
Land, buildings	89,000	93,000
Total	154,144	185,600
Liabilities ($)		
Long-term debt	40,000	37,500
Intermediate-term debt	14,000	34,000
Short-term debt	0	10,000
Total	54,000	81,500
Net worth	100,144	104,100

[a] Land acreage totaled 538 in 1966 and 1970. The crop totals shown here do not include land used for three homesteads and some idle land and woodland.
[b] The farm had three full time nonequivalent laborers throughout the initial study periods, 1966–70.

constraints considered in the MLP model are based on the 1966 farm data. (For a more detailed discussion of the MLP formulation for the application farm, see Chien and Bradford.)

Since a review of the farm records reveals a fairly stable enterprise organization during the initial study periods, 1966–70, the same enterprise activities were considered by the MLP submodel during the experimental study periods, 1971–74. This assumption implies that the entrepreneur's preference for existing enterprises remains unchanged, which does not appear unreasonable, given that the planning horizon was assumed to be five years.

Behavioral constraints built into the simulator to reflect the entrepreneur's behavior regarding period-to-period changes in enterprise levels were applied to beef cow-calf and feeder calf enterprises. All cropping enterprises except burley tobacco were either feed grain or forages, for which the activity levels were primarily dependent upon the size of the beef activities. Thus, once the levels of the beef enterprises were determined, the type and quantity of feeds needed to be produced or purchased would be automatically determined by the simulator. Burley tobacco, being restricted by an allotment, did not need behavioral constraints. The estimates of upper and lower bounds were obtained from the application farm's records. Increases in the cow-calf and feeder numbers were restricted to be less than or equal to 10% and 50% per year, respectively. Yearly decreases could be no greater than 10% for the cow-calf enterprise and no greater than 20% for beef feeders.

Growth of the farm firm was measured using three response variables: total assets, net worth, and changes in size of the beef cattle enterprises. Assets and net worth reflect the financial position, while growth in beef numbers is a special feature of this farm. Simulated and actual levels of the response variables are compared for an initial study period, 1966–70, and an experimental study period, 1971–74 (figures 2 and 3). At the time the model was constructed and first tested, actual

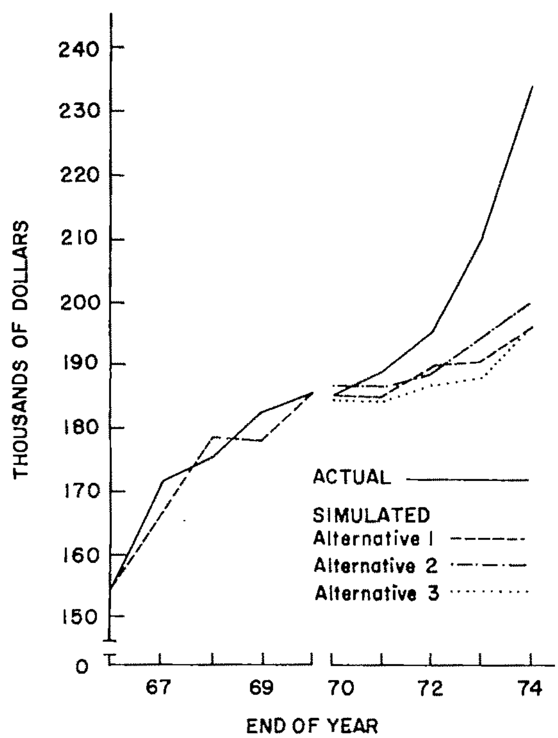

Figure 2. Actual and simulated time paths for firm's total assets

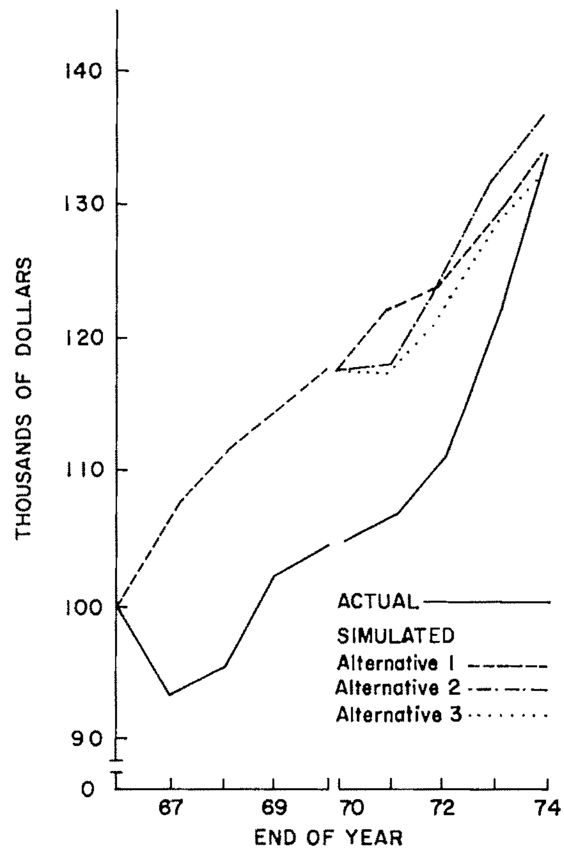

Figure 3. Actual and simulated time paths for firm's net worth

values of response variables were known only for the initial study period, the primary idea being to test the model. Follow-up observations (records) were later obtained for the experimental period for purposes of further testing of initial test conclusions.

Initial Study Period, Testing

For total assets, the simulated response was relatively close to the actual values (figure 2). The simulated time path is neither explosive nor overly damped. Hence, the model possesses at least some of the mechanisms that determine growth in total assets.

The model generated a time path for net worth that after 1967 was consistent with the actual slope but in magnitude was higher than the actual net worth values (figure 3). The departure in magnitude stems from difficulty in accounting for the magnitude of household consumption and from difficulty in incorporating into the model the precise debt payment schedule for the study farm. The farm operator indicated that, because of personal relations with lending agents, he was allowed to retire debts on a very flexible schedule. An examination of farm and household records revealed that over time the operator repaid the loan principal in uneven amounts. Indeed, during the year 1967, the operator actually used some borrowed funds for consumption. Our modified consumption function obviously did not track the behavior for this application firm. Perhaps it is too presumptuous to attempt to a priori track such individual personal behavior especially during any particular year.

Experimental Study Period

Computer-based experiments were conducted with the model to examine the effects of alternative management strategies upon potential growth patterns of the farm firm during 1971–74. Three management strategies (treatments) were compared: continuing fall calving and feeder-cattle operations (a "check treatment"), changing to spring calving and feeder-cattle operations, and adopting a forward pricing or market price hedging strategy with 50% less price variability for feeder calves and feeder cattle.

Experimental results were generated in 1971. Actual values for the response variables (assets or net worth in 1971–74 shown in figures 2 and 3), of course, were not known when these results were generated. Thus, the primary concern should be with comparisons among strategies 1, 2, and 3, not with comparing these strategies to the actual or *ex post* results. The increasing disparity between the actual and projected asset values during the experimental period (1971–74) is largely due to sharp inflationary increases in central Kentucky land values during this period.

Terminal states (end of 1974) of total assets and net worth values were not statistically different among the three strategies. These findings may be partially explained by the fact that spring calving uses pasture as the primary feed, thus reducing the investment in machinery. Consequently, any significant growth in terms of assets or net worth would have to stem from quite a substantial expansion in the beef cow herd, and this is not likely to occur during a period of only four years.

Experimental results also indicated that if the study farm were to continue following fall-calving beef production systems (alternative 1), the size of the breeding herd would have remained constant during the experimental study period (1971–74). However, the number of feeder cattle would have increased from 75 to over 100. This expansion would have stemmed primarily from a reduction in interest expenses and principal payments for the old debts, releasing operating capital for additional feeder cattle.

Substitution of a spring-calving program for the fall-calving operation (alternative 2) would have resulted in expansion of both the beef cow herd size and the feeder cattle enterprise. The number of beef cows in the herd was projected to increase from 71 head at the end of 1970 to 93 head at the end of 1974. The feeder cattle enterprise was projected to expand from 75 to 152 head. This projected expansion can be attributed mainly to the relatively low production costs associated with a spring-calving operation.

The projected enterprise organization under alternative 3 (less price variability) exhibited essentially the same pattern as that of alternative 2. However, projected expansion in the beef cow herd size tended to be more rapid than under alternative 2. Reduction in price uncertainty apparently tends to reduce the complexity of the entire decision-making process, encouraging the operator to expand his farm business whenever markets indicate favorable opportunities.

Summary Remarks

The significance of the farm firm growth modeling described in this article lies in the integration of pertinent economic theories of the dynamic planning behavior of the firm in order to link capabilities of MLP and computer simulation techniques as a means of utilizing their maximum contribution to the prediction of farm firm growth. The integrated multiperiod linear programming, simulation model exhibits descriptive, predictive, stochastic, and dynamic features of the farm firm planning process. This is characterized by the sequential and recursive nature of the model, which contains behavioral constraints, qualitative investment decision rules, and a forecasting technique for stochastic yields and prices.

The empirical illustration indicates that the model is capable of describing and predicting growth patterns of the farm firm. Since the major interest of the economic analyst is to examine average firm growth patterns, the effects of "extreme" values for the stochastic variables may tend to accumulate through the lagged endogenous variables. Such extremes may be averaged out, as Strickland noted, with sufficient replications in the model experiments. Although the model is primarily predictive in nature, experiments allow one to examine the effects of changes in managerial decision processes. Thus, entrepreneurs can identify necessary changes in the firm behavioral mechanisms in order to achieve more nearly optimal behavior consistent with their goals.

Although the use of the model requires a substantial commitment of time and resources for such things as data collection and computer software developments, we believe that the investment is merited because of the importance and complexity of dynamic farm business planning. With an adequate support of software and computer hardware, the proposed modeling technique would be a useful tool to aid the economic analyst in explaining or predicting farm firm growth.

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Estimation of Gain Isoquants and a Decision Model Application for Swine Production

Steven T. Sonka, Earl O. Heady, and P. Fred Dahm

Historic estimates of livestock production functions have used repeated observations on the animals to estimate the overall gain surface. The estimates involve autocorrelation accordingly. To circumvent this problem, gain isoquants are estimated directly by means of an instrumental variable approach. Data are from a swine experiment designed for the purpose with 648 hogs. Protein supplement and corn serve as the substitute inputs. Protein supplement is estimated as the instrumental variable. Isoquant equations then are predicted for three weight intervals. Finally, a decision model is applied for economic choice. Comparisons are made for various price sets of recent years.

Key words: autocorrelation, decision model, instrumental variable, isoquants, production function.

A major consideration in any swine-feeding program is the cost of feed required. For a typical Corn Belt swine operation, feed costs are 55% to 60% of the total cost of raising an animal from weaning to market (Burns). Since feed is a major cost to the producer, he needs information relating to the minimum expenditure needed to attain a specified gain, as well as the time required for the gain.

Recently, uncertainty about the most economic ration has increased because of great fluctuations in the cost of major feeds. For example, after the corn blight of the 1970 season, the ratio of the price of a pound of soybean oilmeal to a pound of corn was 1.43 in mid-April 1971 (USDA). But by mid-April 1973, that same ratio had risen to 3.82, more than 2.6 times that of 1971 (USDA). Faced with these wide price gyrations, recommendations for fixed ration proportions, which fail to take into account economic as well as physical relationships, decline in value for the swine producer (Allison).

Because feed costs are a major component of the total cost of producing swine and because the prices of protein supplement and corn have fluctuated widely in the past few years, information on the proper energy-protein mix for various prices of feeds is needed. The primary goal of the study reported in this paper is to estimate substitution ratios between protein supplement and corn and to develop a relatively simple procedure to calculate proper rations for differing protein-supplement, corn-price relationships. A complementary goal of the paper is to determine the value of such information to the producer.

In this article we first describe the experiment conducted to provide the raw input-output or production function data and the techniques employed to overcome the statistical problems inherent in animal-production function analysis. Then the estimated equations and substitutions ratios between corn and protein supplement are reported. In a final section, we describe a simple decision model for minimizing feed costs, which is relevant to many of the nation's swine producers.

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The Basic Experiment

To determine substitution ratios between protein supplement and corn for growing swine, gain and feed consumption data for 648 animals were analyzed. All of the animals were a three-way cross of Hampshire, Yorkshire, and Duroc breeds and were raised in confinement facilities in pens of six animals. The experiment was designed specifically to allow estimation of gain (production) functions and marginal rates of feed substitution.

The 648 hogs were grouped in five separate experiments with animals within an experiment allotted to replications on the basis of weight, sex, and litter. For three of the experiments (408 animals), the starting weight averaged 60 pounds per head. These animals were fed a growing ration until they reached 100 pounds per animal and then were switched to a finishing ration for the remainder of the experiment. The growing rations incorporated a 45% protein supplement and six protein levels (13%, 14%, 15%, 16%, 17%, and 18%) were used in the rations. The finishing rations incorporated a 41% protein supplement and were fed over two weight intervals or periods, from 100 to 150 pounds and from 150 to 215 pounds. For the first of these two intervals, seven protein levels (10%, 11%, 12%, 13%, 14%, 15%, and 16%) were used; for the second interval, six protein levels (10%, 11%, 12%, 13%, 14%, and 15%) were used.

For the remaining two experiments, containing 240 animals, the starting weight averaged 100 pounds per head and only the finishing ration was fed for the 100 to 150 and the 150 to 215 pound intervals. Therefore, the estimates for the growing weight interval (60 to 100 pounds) are based on 408 animals and the estimates for the finishing weight intervals (100 to 150 pounds and 150 to 215 pounds) are based on data from 648 animals.

Estimation of the Production Relationship

Estimation of meat animal production relationships typically presents the researcher with at least two major econometric problems. The first arises because, normally, successive observations must be taken from the same experimental unit (in this case, a lot of six hogs) as the animals proceed over a gain path (Heady et al.). Because the same experimental unit is used for repeated observations, one assumption used in the ordinary least squares procedure, that of zero covariance for the disturbance terms, can be violated (Johnston).

Although assumptions can be made as to the autoregressive nature of the disturbance terms (Heady et al., Paris et al.), a radically different approach was adopted for this analysis. Normally, a production function is estimated from a series of observations on weight and feed intake and then isoquants for corn and protein supplement are derived (Dillon, Heady and Dillon). For this analysis, however, the total quantity of corn and protein supplement needed by each lot to complete each of the three weight intervals (60 to 100 pounds, 100 to 150 pounds, and 150 to 215 pounds) was calculated. From this, we know the feed necessary to attain a specified amount of weight gain (40 pounds, 50 pounds, and 65 pounds per hog, respectively). Now, instead of estimating the traditional production function, it is possible to directly estimate a gain isoquant over each of the three weight intervals.[1] These isoquants take the form

$$C_i = f_i(PS_i), \tag{1}$$

where PS_i = pounds of protein supplement consumed over the ith weight interval and C_i = pounds of corn consumed during the ith weight interval.

Although this procedure does not supply as much information as does estimation of the total production function in the conventional manner, it does provide direct estimates of the trade-offs (marginal substitution rates) between corn and protein supplement in growing swine. Furthermore, because each experimental unit is used only once in each weight interval, the serial correlation problem caused by using successive observations to estimate a production or gain surface is eliminated.

The second estimation problem arising in animal production studies stems from the basic nature of animal production. This problem arises because the animal, not the experimenter or the farmer, controls the rate at which feed is consumed (Askalani, Johnston). The researcher can dictate how much the ani-

[1] Conventional production functions from the experimental data have been estimated. Isoquants derived from them can be compared with those estimated directly as in this paper. While results are quite similar, the approach presented in this paper seems preferred.

mals eats in a feeding period but not the days needed to consume a set quantity of feed, or the researcher can specify the days in the trial but not the total feed consumed. Because the swine used in this analysis were fed *ad libitum* (i.e., full fed), it would not be proper to consider either the quantity of protein supplement consumed (PS_i) or the quantity of corn consumed (C_i) as fixed variables.

To overcome the serious estimation problem posed by measurement error in the independent variable, an instrumental variable estimator is employed in the analysis (Duloy). This procedure requires an instrumental variable uncorrelated with the equation disturbance term and the measurement errors (Johnston).

As previously noted, when full fed the animal determines the rate of feed consumption in an experiment. The experimenter or the farmer can only control the proportion of the ration that is protein. Therefore, the percentage of protein is the variable of interest for the swine producer. The instrumental variable used in this analysis is then the predicted quantity of protein supplement based on an equation with percentage of protein and percentage of protein squared as independent variables. Among the several evaluated, this algebraic form conformed statistically to the data better than others.

This two-step estimation procedure first requires estimation of the instrumental variable (predicted protein supplement). This equation is

$$PS_i = g(R_i), \tag{2}$$

where R_i = the percentage of protein in the ration in weight period i and PS_i is defined as before. An equation in the form of equation (2) is estimated for each weight interval and used to determine a predicted quantity of protein supplement consumption for each experimental unit. This predicted protein supplement quantity is then used to determine that isoquant equation as given in

$$C_i = h(PS^*_i), \tag{3}$$

where PS^*_i = the predicted quantity of protein supplement from equation (2) for the ith weight period and C_i is defined as before. Because the actual isoquant equation utilizes predicted protein supplement, ordinary least squares applied to this equation gives the instrumental variable estimates.

For each weight interval, one equation is needed to predict the quantity of protein supplement consumption and another equation must be estimated to determine the relationship between protein supplement and corn. Because the percentage of protein in the ration also affects the rate of gain an animal can attain, a third equation is estimated that relates the number of days needed to attain the specified gain to the percentage of protein in the ration as in

$$D_i = k(R_i)\ , \tag{4}$$

where D_i = the number of days required to complete the ith weight interval and R_i is defined as before.

Estimation Results

Instrumental Variable Equations

For each weight interval, the equations estimating the relationships between protein supplement consumption and the percentage of protein in the ration are[2]

(5) Interval I (60 to 100 pounds):

$$\ln PS_1 = -\underset{(2.12)}{1.6931} + \underset{(4.68)}{0.4832}\ R_1 - \underset{(3.57)}{0.0118}\ R_1^2,$$
$$R^2 = 0.899 \qquad F = 288.88;$$

(6) Interval II (100 to 150 pounds):

$$\ln PS_2 = -\underset{(7.95)}{3.4830} + \underset{(11.54)}{0.7962}\ R_2 - \underset{(8.45)}{0.0225}\ R_2^2,$$
$$R^2 = 0.956 \qquad F = 1{,}110.42;$$

and

(7) Interval III (150 to 215 pounds):

$$\ln PS_3 = -\underset{(10.25)}{5.1616} + \underset{(13.55)}{1.1035}\ R_3 - \underset{(10.57)}{0.0344}\ R_3^2,$$
$$R^2 = 0.962 \qquad F = 1{,}317.03;$$

where PS_i and R_i are defined as before. The conventional R^2 and F-statistics also are included for each estimated equation. (The figures in parentheses are t-values for the estimated statistics.)

Isoquant Equations

Equations (5), (6), and (7) are used to determine predicted protein supplement consumption data for each weight interval. These predicted values are then used as independent variables in the following isoquant equations:

[2] The figures enclosed in parentheses are t-values for each coefficient.

(8) Interval I (60 to 100 pounds):

$$\ln C_1 = \underset{(32.99)}{6.1630} - \underset{(9.33)}{0.5898} \ln PS^*_1,$$
$$R^2 = 0.740 \qquad F = 188.13;$$

(9) Interval II (100 to 150 pounds):

$$\ln C_2 = \underset{(63.26)}{6.2292} - \underset{(13.14)}{0.4405} \ln PS^*_2,$$
$$R^2 = 0.691 \qquad F = 232.39;$$

and

(10) Interval III (150 to 215 pounds):

$$\ln C_3 = \underset{(81.61)}{6.4378} - \underset{(14.16)}{0.3526} \ln PS^*_3,$$
$$R^2 = 0.769 \qquad F = 346.43;$$

where C_i and PS^*_i are defined as before.

Equations (8), (9), and (10) describe the substitution of corn and protein supplement for each weight interval and are graphed in figures 1, 2, and 3, respectively. Each of these contours indicates the predicted combinations of corn and protein supplement that can be used to attain the gains specified for each weight interval.

The slope of an isoquant at any particular point is of course the marginal rate of substitution of protein supplement for corn (and vice versa). Marginal rates of substitution for the three interval isoquants at various protein supplement levels are given in table 1.

Within each weight interval, the data of table 1 indicate that the rate of replacement of corn by protein supplement declines as more protein supplement is included in the ration. In interval I, for example, 1 pound of protein supplement replaces 5.39 pounds of corn at 12 pounds of protein supplement but only 2.39 pounds at 20 pounds of protein supplement. Similar diminishing marginal substitution rates prevail over other weight intervals. The data of table 1 also indicate that the replacement of corn by protein supplement declines as an animal shifts from the growth stage of development to the fattening stage. For example, at 24 pounds of protein supplement in interval I, 1 pound of protein supplement replaces 1.79 pounds of corn; at the equivalent protein supplement level in interval II, 1 pound of protein supplement only replaces 1.67 pounds of corn; and at the equivalent protein supplement level of interval III, 1 pound of protein supplement replaces 1.55 pounds of corn.

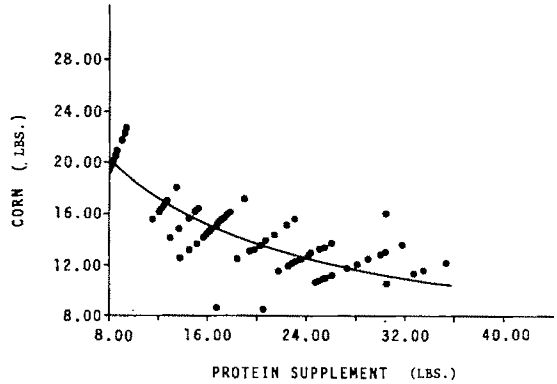

Figure 2. Interval II isoquant (● = original observation)

Time of Gain Equations

The classical textbook isoquant supposes that time is constant as the specified level of production is attained by any one of a range of input ratios x_i/x_j, where x_i and x_j are the inputs being substituted for each other. However, while the mix of inputs may not change the time period for the isoquant in certain industrial processes, it does for inputs such as corn

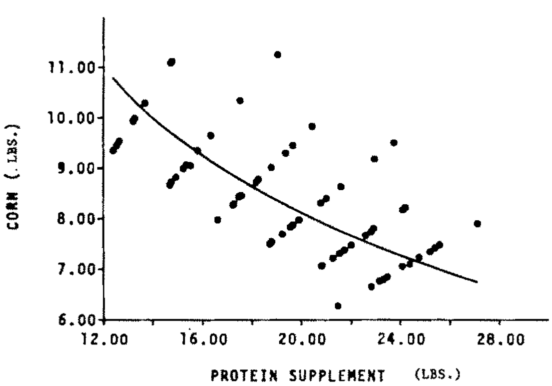

Figure 1. Interval I isoquant (● = original observation)

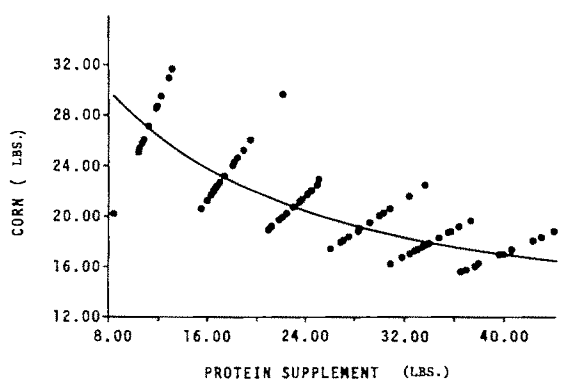

Figure 3. Interval III isoquant (● = original observation)

Table 1. Marginal Rates of Substitution of Protein Supplement for Corn

Pounds of Protein Supplement in Period I*	Interval I		Interval II		Interval III	
	Percentage of Protein	Substitution Rates	Percentage of Protein	Substitution Rates	Percentage of Protein	Substitution Rates
12.0	12.5	5.39	11.8	4.52	11.5	3.96
16.0	14.2	3.41	13.0	2.99	12.7	2.69
20.0	16.0	2.39	14.3	2.16	13.8	1.99
24.0	17.9	1.79	15.6	1.67	14.9	1.55
28.0	20.0	1.40	16.8	1.33	15.9	1.26

* Because the three weight intervals are defined for different quantities of gain, the protein supplement levels of period I were converted into pounds of protein supplement per pound of gain, and this ratio was used to determine equivalent protein supplement quantities for intervals II and III. The equivalent levels are 15, 20, 25, 30, and 35 pounds in interval II and 19.5, 26.0, 32.5, 39.0, and 45.5 pounds in interval III.

and protein supplement used in a biological production process such as swine. This problem has been discussed elsewhere (Heady and Dillon, pp. 291–99) and a pork costulator was devised (p. 301) to allow the producer to select between the least-cost ration and the least-time ration, if the latter allowed marketing hogs during a period of higher prices. We treat time of gain in a somewhat different manner here.

Although feed constitutes the major portion of the total production costs for swine, labor and capital costs also are important. Both latter cost components are affected by the number of animals the farmer can feed in a year and therefore by the time required to feed out a group of hogs. Also, because the price received for hogs varies, the farmer may decide to feed a higher cost ration if a faster rate of gain allows him to receive a higher price for his product. Because of these time-influenced considerations, the relationship between the time required to gain a specified weight and composition of the ration were estimated and are presented:

(11) Interval I (60 to 100 pounds):

$$D_1 = \underset{(6.04)}{122.0728} - \underset{(4.29)}{11.2051}\, R_1 + \underset{(3.82)}{0.3191}\, R_1^2,$$
$$R^2 = 0.646 \qquad F = 59.42;$$

(12) Interval II (100 to 150 pounds):

$$D_2 = \underset{(10.47)}{259.1969} - \underset{(8.51)}{33.0176}\, R_2 + \underset{(7.77)}{1.1709}\, R_2^2,$$
$$R^2 = 0.643 \qquad F = 92.83;$$

and

(13) Interval III (150 to 215 pounds):

$$D_3 = \underset{(8.04)}{270.9710} - \underset{(6.30)}{34.3196}\, R_3 + \underset{(5.69)}{1.2368}\, R_3^2,$$
$$R^2 = 0.579 \qquad F = 70.91;$$

where D_i and R_i are defined as before.

These equations indicate that as the percentage of protein in the ration increases, the number of days needed to attain the specified gain declines but at a diminishing rate. This relationship is further illustrated in figures 4, 5, and 6, which graph actual and predicted data for equations (11), (12), and (13).

Economic Implications

The equations and relationships presented in the previous section describe the physical process of the growing animal. These data provide only part of the information needed by the pork producer in determining the economically-optimum ration. He requires a decision criteria that will allow him to select the minimum-cost ration given his constraints. In this section, therefore, a simple decision process for selecting a least-cost ration is described. This process is adequate for a large portion of the nation's pork producers.

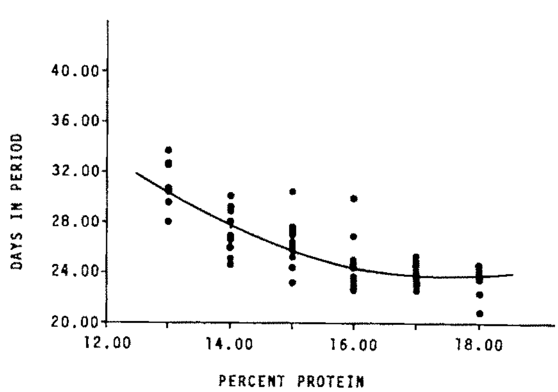

Figure 4. Days in period I (● = original observation)

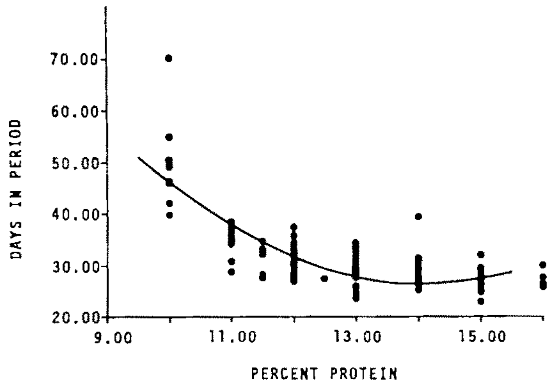

Figure 5. Days in period II (● = original observation)

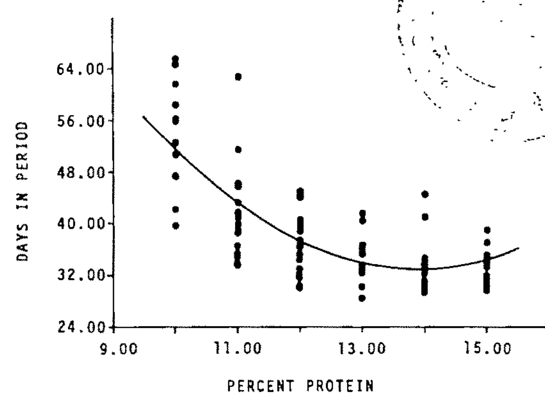

Figure 6. Days in period III (● = original observation)

The Decision Model

The decision rule adopted for this analysis is based on maximization of profit in an unconstrained optimization framework. In this formulation, maximum profit is attained when corn and protein supplement are mixed in a ratio that allows the marginal rate of substitution of protein for corn to just equal the protein-supplement, corn-price ratio. This equality can then be rearranged to solve for an optimum quantity of protein supplement as in

$$(14) \qquad \overline{PS}_i = [(P_{ps}{}^i/P_c)/a_i]^{b_i},$$

where $\overline{PS}_i$ = the optimum quantity of protein supplement in weight interval i, $P_{ps}{}^i$ = the price of protein supplement in the ith interval, P_c = the price of corn, and a_i and b_i = constants for interval i (derived from the marginal rate of substitution equations).[3]

For each weight interval, the optimal quantity of protein supplement ($\overline{PS}$) determined in equation (14) can then be inserted into the proper isoquant equation for each interval, equation (8), (9), or (10), and an optimal quantity of corn can then be calculated. But, as mentioned earlier, the farmer does not control the quantity of feed consumed in an *ad libitum* feeding system. He can only control the percentage of protein in the ration. It is easy to calculate the optimum percentage, however, given the data available. This calculation is

$$(15) \quad \overline{R}_i = (\overline{PS}_i PPS_i + \overline{C}_i PC)/(\overline{PS}_i + \overline{C}_i),$$

where $\overline{R}_i$ = the optimum percentage of protein for interval i, $\overline{C}_i$ = the optimum quantity of corn for interval i, PPS_i = the percentage of protein in the protein supplement fed in period i (either 45% or 41%), PC = the percentage of protein in corn, and $\overline{PS}_i$ is defined as before.

The decision process just described would insure least-cost pork production if the farmer had no alternative uses for the fixed resources allocated to swine production. This would be relevant for the producer who farrows only once a year and whose swine equipment and buildings lie idle after his one batch of hogs is fed. But because many producers do not conform to this situation, the decision process was extended to take into account the time required for the production process. For each weight interval, the optimal percentage of protein ($\overline{R}_i$) can be inserted into the proper time of gain equation, equation (11), (12), or (13), and the total number of days needed to complete the production process determined.

If the hog feeder either farrows or purchases his replacement animals at specified times, he can then determine if the optimum feed mix (with no time constraint) will result in completion of the production process sufficiently soon to free his facilities for the next group of feeder animals. If not, he can adjust the percentage of protein in the ration until his time constraint is satisfied.[4] A numerical example

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[3] Statistical analysis of the experimental data indicated that ration carry-over effects from one interval to the next were not significant. This result would seem to be plausible only when a narrow range of rations is considered, as in this example, and when none of the rations evaluated are severely nutritionally deficient.

[4] The only type of producer for which this process is not sufficient is one who can acquire replacement animals immediately after marketing each group of animals. The criteria for this producer would be to maximize profit per day (Dillon) as given in

$$(17) \qquad \pi/D = P_y Y - S - \sum_{i=1}^{3} (P_c C_i + P_{ps}{}^i PS_i)/\sum_{i=1}^{3} D_i,$$

where π/D = profit per day, S = the fixed setup cost per time period, P_y = the expected price of swine at finishing, D_i = the number of days needed to complete the ith interval with the optimum ration, Y = the finished weight of the animal (215 pounds), and P_c, C_i, $P_{ps}{}^i$, and PS_i are defined before.

Table 2. Least-Cost Rations for Actual Protein-Supplement, Corn-Price Ratios of the Last Five Years

	Interval I			Interval II			Interval III		
	Price Ratio[a]	Percentage of Protein	Days Required	Price Ratio[a]	Percentage of Protein	Days Required	Price Ratio[a]	Percentage of Protein	Days Required
Apr. 1975[b]	1.34	18.0	23.8	1.23	16.0	30.6	1.23	15.0	34.4
Nov. 1974[b]	1.18	18.0	23.8	1.08	16.0	30.6	1.08	15.0	34.4
Apr. 1974[b]	1.34	18.0	23.8	1.24	16.0	30.6	1.24	15.0	34.4
Nov. 1973	1.93	17.3	23.7	1.77	15.2	27.9	1.77	14.2	33.0
Apr. 1973	3.62	13.9	27.9	3.33	12.6	29.2	3.33	12.0	37.5
Nov. 1972	2.86	15.2	25.5	2.63	13.4	27.0	2.63	12.7	34.6
Apr. 1972	2.33	16.2	24.3	2.15	14.3	26.5	2.15	13.4	33.1
Nov. 1971	2.17	16.6	24.0	2.00	14.6	26.8	2.00	13.7	32.9
Apr. 1971[b]	0.95	18.0	23.8	0.88	16.0	30.6	0.88	15.0	34.4
Nov. 1970[b]	1.12	18.0	23.8	1.03	16.0	30.6	1.03	15.0	34.4

[a] Each price ratio compares the price of a pound of protein supplement to the price of a pound of corn. The protein supplement used in this example is a mixture of 44% soybean oilmeal, meat and bone meal, salt, and minerals. The prices used are midmonth prices for the specified dates on a Chicago basis (USDA).
[b] Whenever the protein percentage recommended by the decision process exceeds the protein levels actually used in the basic experiment it is assumed that the maximum percentage actually used (18% in interval I, 16% in interval II, and 15% in interval III) would be recommended and the days would correspond to that protein level.

of the decision process is given in the following section.

Empirical Examples

To illustrate the effect feed price fluctuations might have on formulation of a least-cost ration, percentage protein recommendations have been generated using mid-April and mid-November prices of the last five years. Table 2 presents these protein percentages as well as the actual protein-supplement, corn-price ratios and the estimated number of days needed to complete each interval.

The data of table 2 indicate the extent to which feed prices have varied in the last five years. After the corn blight of 1970, the protein-supplement, corn-price ratio fell, reaching 0.95 for interval I and 0.88 in intervals II and III in April 1971. But as the world demand for soybean oilmeal expanded (in part due to a poor anchovy harvest), the price of protein supplement increased at a much faster rate than did the price of corn. By April 1973, the protein-supplement, corn-price ratio had reached 3.62 for interval I and 3.33 for intervals II and III. But after that point, the price ratio of protein supplement to corn receded, being 1.34 for interval I and 1.23 for intervals II and III in April 1975.

Reacting to these wide price fluctuations, the protein percentage recommended by this decision process varies considerably. For each of the weight intervals, the lowest protein recommendations, 13.9%, 12.6%, and 12.0%, would have occurred in April 1973. But with relatively cheaper protein supplement, the optimal protein percentage increases, both before and after that date.

During both the early and the later periods of the last five years, the price of corn was high relative to the price of protein supplement. For five dates (November 1970, April 1971, April 1974, November 1974, and April 1975), the recommended percentage exceeds the highest percentage considered in the analysis. For those five periods, therefore, a recommendation equal to that highest protein percentage in the experiment (18% in interval I, 16% in interval II, and 15% in interval III) would be provided to the swine producer.

Each of these protein recommendations implies a different length of time to complete the growth process. These time requirements are also detailed in table 2 and would give the pork producer an indication of the time period for which his facilities would be utilized by one group of animals.[5] For example, feeding the ration recommended for April 1973 requires ninety-five days to complete the growing process. If this period was too long to allow mar-

[5] Since rate of growth is greatly affected by such things as genetic characteristics, weather stress, and breed, in addition to ration composition, it may be more useful to the individual producer to present the time requirements in terms of deviation from the average length of time required. Then, using an average finishing period relevant for his own system and animals, he could consider the effect of different rations on utilization of his facilities.

keting at a specific price peak or to free facilities for another farrowing, the producer could introduce more protein into the ration to shorten the feeding time.

As further illustration of an application of the isoquant equations derived previously, the rations of table 2 can be compared with a recommended ration that does not take into account fluctuations in feed prices. To determine such a standard ration, equations (11), (12), and (13) can be used to indicate the ration that will achieve maximum rate of gain by solving equation (15) for R_i:

$$\frac{\alpha D_i}{\alpha R_i} = 0. \tag{16}$$

Applying this formulation to each of equations (11), (12), and (13) results in estimates of protein percentages for maximum daily rate of gain of 17.56% for interval I, 14.10% for interval II, and 13.87% for interval III. The second derivative for each equation is positive; thus, conditions for minimization are met. Converting these percentages to whole numbers, as would be practically useful, and inserting the rounded values into the proper time of gain equation results in an eighty-three-day minimum requirement for completion of the growing and finishing periods.

Cost of feed required using the least-cost rations can be compared with the cost of feed using the standard ration. (The protein recommendations of the standard ration, 18%, 14%, and 14%, are also consistent with general swine-feeding recommendations (National Academy of Sciences). For each of the ten dates identified in table 2, feed cost and time requirements of the least-cost recommendations are compared with those of the standard ration in table 3.

A number of interesting factors are identified by the data of table 3. One of the most striking of these items is the almost doubling of feed costs from the first part of the 1970s to the latter part of the five-year period. This sudden surge in input costs illustrates the pressure placed on livestock producers in recent years.

The comparison data for feed costs show that the cost savings per head from using a least-cost ration are rather small. Of course, when applied to all the animals a producer has on feed over a number of years the savings grow to be more substantial. Also when both corn and protein prices are at higher levels, as in the last few periods, the potential for savings increases. When protein prices are high relative to the price of corn (as in April 1973), the cost advantage of using a lesser quantity of protein improves.

The data of table 3 also indicate that the number of additional days required by using the least-cost ration are generally quite small. This slight increment in time on feed indicates that the least-cost recommendations could be useful to many of the nation's hog producers who have some slack time between groups of animals on feed. Except for the April 1973 example, the additional days required comprise less than a week; and in the April 1973

Table 3. Comparison of Feed Costs and Time Requirements for Least-Cost Rations with Those of a Standard Ration

	Least-Cost Ration						
	Percentage of Protein						
	Interval I	Interval II	Interval III	Feed Cost[a]	Days Required	Feed Cost Compared to Standard Ration[b]	Days Required Compared to Standard Ration[b]
Apr. 1975	18	16	15	24.30	89	−0.30	6
Nov. 1974	18	16	15	29.43	89	−0.47	6
Apr. 1974	18	16	15	22.48	89	−0.28	6
Nov. 1973	17	15	14	23.49	84	−0.05	1
Apr. 1973	14	13	12	18.32	93	−0.68	10
Nov. 1972	15	13	13	13.88	87	−0.17	4
Apr. 1972	16	14	13	12.54	85	−0.04	2
Nov. 1971	17	15	14	10.15	84	−0.01	1
Apr. 1971	18	16	15	13.42	89	−0.13	6
Nov. 1970	18	16	15	12.59	89	−0.05	6

[a] Over the three intervals.
[b] The standard ration as defined here recommends 18% protein in interval I, 14% protein in interval II, and 14% protein in interval III. This ration results in maximum rate of gain and 83 days would be required with this ration.

case, the potential for savings in feed costs was the highest of the periods analyzed.

The small savings in feed costs per head indicated in table 3 underscores the need for decision procedures that provide information at low cost. Decision procedures that involve relatively high acquisition and utilization costs may not be attractive to producers when the savings to be gained are small.

Summary

The analysis discussed in this paper determined substitution ratios between protein supplement and corn for growing and finishing swine and illustrated how these ratios could be used to calculate least-cost rations for swine. The estimation process adopted here involved direct determination of gain isoquants to overcome the autocorrelation problems usually inherent in livestock production analysis. Because the independent variable, protein consumption, was a random variable correlated with the disturbance term of the isoquant equation, an instrumental variable procedure was also utilized.

The substitution ratios resulting from the estimation procedure were generally consistent with expected nutritional constraints. One pound of protein supplement could substitute for a lesser quantity of corn as the percentage of the ration that was protein supplement increased. Also, 1 pound of protein supplement replaced a larger quantity of corn for smaller animals than for larger.

The decision process illustrated in this article was based on the decision rule of maximization of profit. Time was not directly introduced into the decision process although estimates of the time required to reach market weight were presented. The resulting rations may not be proper, therefore, for farmers who run a continuous feeding system and have replacement animals available immediately after facilities become empty. The decision process presented here, however, is relevant for that segment of the swine industry that does not have replacement animals available instantaneously. The empirical examples calculated for this article show that the large feed price swings of the recent past should result in ration changes to achieve least-cost production. The decision process presented here also has the advantage of being simple enough to be used by farmers either by using a mechanical device similar to the "Pork Costulator" (Heady and Dillon) or tables of price ratios and protein percentages. The estimates of feed cost savings generated in the paper underscore the need for a relatively simple and inexpensive decision aid if it is to be useful to producers.

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Recent Changes in Beef Grades: Issues and Analysis of the Yield Grade Requirement

Wayne D. Purcell and Kenneth E. Nelson

The recent change in beef grades has stimulated discussion and opposition. Changes designed to improve the efficiency of the beef-marketing system are being opposed by groups who adopt a micro perspective. The move to required yield grading continues to draw opposition. Analysis of original data from 118 beef carcasses and data from published studies indicates trimming procedures on fabricated cuts are important determinants of the change in cutability across yield grades. Research designed to investigate the implications of different trimming procedures is needed to clarify the applicability of yield grades.

Key words: applicability, cutability, trimming procedures, value differences, yield grades.

Grades and grading are an integral part of the beef-marketing system. Much has been written on such subjects as the economic function of grades, what constitutes an effective set of grading standards, and the role that grades have played in the changing structure of the beef industry. Particular attention has always been paid to proposed revisions in either grade standards or grading procedures. In the 1960s there were two important sets of proposed changes. First came the dual grading system proposal of 1962 and then the change in marbling requirements and the introduction of separate yield grades in 1965.

The period 1965–73 was free of major change. On 10 September 1974, a series of significant changes in beef grade standards was proposed by the U.S. Department of Agriculture. They were elimination of conformation as a factor in determining quality grade, initiation of a "flat-line" marbling requirement for the Prime, Choice, Good, and Standard grades that eliminated the requirement for increased marbling during A maturity (nine to thirty months of age), and initiation of required yield grading for all carcasses that are quality graded.

A ninety-day period for comments followed the September 10 announcement. The comments were evaluated, and in early March 1975 the USDA announced the new standards and procedures would go into effect on April 15. On April 11, however, a coalition of independent packers and consumer advocate groups secured a court injunction and blocked enactment of the proposed changes. The injunction was set aside in response to a USDA appeal in November 1975. On 13 January 1976, the USDA announced the new standards would go into effect on February 23. Efforts to secure a second court injunction were denied and the new procedures were instigated. In early March, however, court actions were continuing in an attempt to have all or part of the new procedures discontinued.

The purpose of this paper is two-fold. First, attention is drawn to the reasons for the opposition to the changes in beef grades. Second, the informational base underlying the move to required yield grading is examined. The results of a detailed cutability analysis of 118 beef carcasses are reported as a contribution to the literature that establishes the quantitative relationship between yield grades and changes in carcass cutability.[1]

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[1] Cutability is used to describe the percentage estimated by the following ratio: (weight of lean, retail cuts from a beef carcass)/(cold carcass weight).

The Competing Factions and a Changing Environment

Reaction to the proposed changes was and is affected by the internal dimensions of the beef marketing system. The USDA promotes change that would facilitate attainment of traditional objectives such as increases in pricing efficiency, more accurate identification of product value, and increases in overall production efficiency. Realization of these objectives could improve efficiency of the beef-marketing system as a whole. But decision makers at any one stage in the system operate from a somewhat different perspective. The manager of an individual firm tends to focus on short-run implications of change and to worry first about firm interests and not the needs of the system as a whole. Changes in grades and grading procedures are likely to be opposed if the changes appear to threaten the competitive position of the firm or require change in procedure internal to the firm.

Such opposition to change in the grading standards is not new. The dual grading proposal of 1962 eliminated conformation as a variable in determining quality grade and introduced a "dual" grade to measure carcass cutability (Grange 1972). Producer groups objected to the elimination of conformation, and a compromise position was adopted by the USDA in its 1965 announcement (Grange 1975). Conformation was reinstated as a factor in determining quality grade. Yield grades, measuring cutability differences, were introduced as separate grades.

A new faction became active in opposition to the 10 September 1974 proposal. Consumer advocate groups opposed the proposed changes in marbling requirements. They contended that the "flat-line" approach to marbling requirements would mean a significant reduction in quality of product with no assurance of a concurrent reduction in price; that is, consumers would be forced to pay Choice prices for Good grade beef. Working with a group of independent packers who opposed required yield grading, the consumer groups helped secure the original court injunction.

A significant body of literature largely invalidates the contentions of the consumer groups with regard to the suggested decrease in quality. Available research results that test the relationship between marbling and overall eating quality reveal a positive but very small correlation (Dunsing, Jeremiah et al., Parrish et al.). In the *Federal Register,* the Agricultural Marketing Service, USDA, having reviewed the literature, concluded ". . . that in beef from cattle up to about 30 months of age (A maturity) changes in maturity have no significant effect on beef palatability" (Peterson, p. 11,536).

Several producer groups took the other side and applauded the proposed changes. Among the potential benefits mentioned were decreased slaughter weights due to the flat-line marbling requirement, improved grain conversion rates given anticipated 15 to 30 pound reductions in fed cattle slaughter weights that eliminate gain at the end of the feeding period when conversion rates (and the marginal cost of production) are relatively high, and increased pricing efficiency as a result of the required yield grading that identifies value differences due to variations in cutability within the Choice or other quality grade and brings these value differences into the pricing process. Earlier economic analyses have supported the positive position taken by these producer groups (Nelson and Van Arsdall, Purcell).

The provision calling for required yield grading continues to draw adamant opposition from beef packers. Most observers, including USDA officials, agree this is the part of the proposed changes that is most important from an economic viewpoint and the change most likely to precipitate long-run adjustments.

The message to be gleaned from the events of the period from 10 September 1974 through early 1976 is clear: change in the beef-grading standards, even change that has solid theoretical support, is likely to be opposed unless all groups that feel they will be affected are convinced of the merits of the proposed change. Attention therefore shifts to the adequacy of the informational base that supports the changes. The remainder of this analysis examines the informational base underlying the move to required yield grading.

The Change to Required Yield Grading

The theoretical and empirical support for the use of a mechanism to measure differences in carcass cutability is impressive. Differences in cutability within the Choice (or other) quality grade are well documented (Dinkel et al.; Epley et al.; Henrickson and Monroe; Stringer et al.). Such differences in cutability

Table 1. Distribution of Carcasses Used in Developing the Murphey Equation by Grade and Class

Grade	Class			Total by Grade
	Steers	Heifers	Cows	
		(No. of Head)		(No. of Head)
Prime	19	4	—	23
Choice	19	23	—	42
Good	23	13	—	36
Standard	14	4	—	18
Commercial	—	—	20	20
Utility	8	—	11	19
Cutter	—	—	2	2
Canner	—	—	2	2

Source: Murphey et al.

cause significant variation in carcass value. The adoption and use of a mechanism such as yield grading seems imperative if these value differences are to be brought into price negotiations and provide for price premiums or discounts.

Yield grading appears to be consistent with the commonly stated theoretical goals of grading. Breimyer notes that one of the objectives of grading is to provide a vehicle for sending signals up and down the production-distribution lines (p. 6). The principal objective of an ideal standard should be to aid the consumer in telling the producer what she or he considers desirable by setting up a chain of information between consumer and producer (Kohls, p. 287). Marketing economists discuss the issue under the label of "pricing efficiency." For yield grades to significantly improve the level of pricing efficiency, it would appear that at least two requirements must be met. First, yield grades must be broadly used. It is difficult to generate consistent and identifiable price signals when part of the carcasses are yield graded and the remaining carcasses are priced using other criteria of value. But a second requirement, one that must be met before widespread adoption could be expected, is that of applicability under industry operating conditions.

Development of Yield Grades

Examination of the literature reveals the base for the USDA's yield grade standards was developed in a paper by Murphey and associates in 1960. The distribution of the carcass data used in estimating the parameters of the Murphey equation is presented in table 1 by classes and grades.

When the yield grades were officially introduced in 1965, five yield grades were identified. According to the standards, a beef carcass typical of a yield grade will cut out 2.3% more lean, semiboneless retail cuts from the round, loin, rib, and chuck than a carcass of the next lower (higher number) yield grade (Murphey et al.). For the entire carcass, however, the reported difference in lean retail cuts is 4.6% of carcass weight per yield grade (USDA 1968). Estimates of percentage differences in yield of lean cuts for the total carcass are published monthly in the USDA's *Livestock, Meat and Wool Market News* with accompanying estimates of value differences between yield grades.

Research on Cutability

The research reported in this paper, hereafter referred to as the Purcell-Nelson study, details cutout tests conducted on 118 beef carcasses in a commercial breaking plant. A total of 83 of the 118 carcasses were graded Choice or better (four graded Prime) and the remaining thirty-five were graded Good. The distribution of the 118 carcasses by yield grade groupings is shown in table 2.

All carcasses were broken to the same set of boneless retail cuts, a set of cuts contained in the USDA's Institutional Meat Purchase (IMP) Series 100 specifications (USDA 1970).

Table 2. Distribution of the 118 Steer Carcasses Analyzed by Yield Grade Groupings

Yield Grade Grouping	No. of Carcasses
1.0–1.9	3
2.0–2.9	16
3.0–3.9	59
4.0–4.9	31
5.0–5.9	9

Table 3. Fat Limitations on Wholesale and Fabricated Cuts of Fresh Beef

Maximum Average Thickness of Surface Fat (inches)	Related Maximum Thickness at Any One Point (inches)
1.0	1.25
0.75	1.0
0.5	0.75
0.25	0.5

Source: USDA 1970.

Consistent with the breaker's normal procedure, each cut was trimmed to the dual requirements of a maximum fat cover of 0.75 inch at any point and an average fat cover of no more than 0.5 inch. These "fat cover tolerances" are slightly below the middle of the USDA's IMP Series 100 specifications as reproduced in table 3. The only control exercised by the research team was control over the pace of activity to insure each lean cut, piece of bone, and scrap of fat could be accurately weighed and identified with the correct carcass. The regular crew did the breaking via a conventional on-the-table breaking procedure.[2]

Equations (1) through (6) are estimated "cutability equations" from the generated data for selected dependent variables. In general, the explanatory variables—the variables that were used in the Murphey cutability equation—exhibit estimated parameters that are statistically significant. However, the coefficient of determination (R^2) for each equation is lower than a priori expectations, suggesting sources of variability not accounted for in the equations influence the yield of lean cuts. Standard errors for the estimated coefficients are shown in parentheses:

$$(1)\quad \begin{aligned} PT7PCW &= \underset{(1.4689)}{78.0116} - \underset{(0.0020)}{0.0057HCWT} - \underset{(0.3748)}{1.0000BFTHKNS} - \underset{(0.2295)}{0.3387KHP} + \underset{(0.0879)}{0.218REA}, \quad R^2 = 0.287; \end{aligned}$$

$$(2)\quad \begin{aligned} P7PCW &= \underset{(1.5473)}{46.8921} - \underset{(0.0021)}{0.0092HCWT} - \underset{(0.3948)}{1.3102BFTHKNS} - \underset{(0.2417)}{0.2763KHP} + \underset{(0.0926)}{0.4003REA}, \quad R^2 = 0.410; \end{aligned}$$

$$(3)\quad \begin{aligned} PT4PCW &= \underset{(1.7454)}{68.6375} - \underset{(0.0023)}{0.0113HCWT} - \underset{(0.4454)}{1.402BFTHKNS} - \underset{(0.2727)}{0.7791KHP} + \underset{(0.1045)}{0.2940REA}, \quad R^2 = 0.428; \end{aligned}$$

$$(4)\quad \begin{aligned} P4PCW &= \underset{(1.5441)}{43.5117} - \underset{(0.0021)}{0.0098HCWT} - \underset{(0.3940)}{1.2340BFTHKNS} - \underset{(0.2413)}{0.2882KHP} + \underset{(0.0924)}{0.3808REA}, \quad R^2 = 0.408; \end{aligned}$$

$$(5)\quad \begin{aligned} PT3PCW &= \underset{(1.1225)}{9.9971} + \underset{(0.0015)}{0.0045HCWT} + \underset{(0.2864)}{0.3958BFTHKNS} + \underset{(0.754)}{0.4289KHP} + \underset{(0.0672)}{0.0012REA}, \quad R^2 = 0.210; \end{aligned}$$

and

$$(6)\quad \begin{aligned} P3PCW &= \underset{(0.3877)}{3.3803} + \underset{(0.0005)}{0.0006HCWT} - \underset{(0.0989)}{0.0762BFTHKNS} + \underset{(0.0606)}{0.0119KHP} + \underset{(0.0232)}{0.0195REA}, \quad R^2 = 0.035. \end{aligned}$$

The variable names used in the analysis are $P7PCW$ = lean cuts from seven primals as percentage of cold carcass weight; $PT7PCW$ = lean cuts from seven primals as percentage of cold carcass weight, lean trim included;[3] $P4PCW$ = lean cuts from four major primals as percentage of cold carcass weight;[4] $PT4PCW$ = lean cuts from four major primals as percentage of cold carcass weight, lean trim included; $P3PCW$ = lean cuts from three minor primals as percentage of cold carcass weight;[5] $PT3PCW$ = lean cuts from three minor primals as percentage of cold carcass weight, lean trim included; $HCWT$ = hot carcass weight (pounds); $BFTHKNS$ = back fat thickness (inches); KHP = kidney, heart fat as percentage of carcass weight (%); and REA = ribeye area (square inches).

Equations (7) through (12) are estimated functional relationships with cutability as the dependent variable and yield grade (YG), to the nearest 0.1, as the single explanatory variable. The estimates of the slope coefficients are highly significant, but estimates of R^2 are relatively low. The estimated parameters for

[2] More detail on research design and analytical procedure is available from the authors.

[3] The lean trim was both 50-50 trim (50% lean) and 75-85 trim (75–85% lean).

[4] The four major primals are the loin, rib, round, and chuck.

[5] The three minor "primals" are the brisket, plate, and flank.

the yield grade variable indicate the change in cutout of lean boneless retail cuts per yield grade. The −0.81 to −1.15 range for all equations except equations (11) and (12), which deal with the three minor "primals," is revealing. Equation (7) provides an estimate of the relationship between lean cuts from the total carcass, including lean trim, and yield grade. Examination of the implicit ratio of the estimated parameter to the standard error indicates the estimate is highly significant. However, at a level of −0.8069 the change in cutability per yield grade would be less than the 4.6% reported by the USDA (1968). Equation (9), employing lean cuts plus trim from the four major primals, indicates the change in cutout from the four major primals would be 1.1457% per yield grade. Equations (8) and (10) give estimates of the slope coefficients between those of equations (7) and (9):

(7) $$PT7PCW = \underset{(0.4751)}{78.5163} - \underset{(0.1249)}{0.8069}YG, \quad R^2 = 0.264;$$

(8) $$P7PCW = \underset{(0.4643)}{47.3189} - \underset{(0.1221)}{1.1036}YG, \quad R^2 = 0.413;$$

(9) $$PT4PCW = \underset{(0.5640)}{64.8720} - \underset{(0.1483)}{1.1457}YG, \quad R^2 = 0.340;$$

(10) $$P4PCW = \underset{(0.4701)}{43.1566} - \underset{(0.1236)}{1.0737}YG, \quad R^2 = 0.394;$$

(11) $$PT3PCW = \underset{(0.3629)}{13.7039} + \underset{(0.0954)}{0.3203}YG, \quad R^2 = 0.088;$$

and

(12) $$P3PCW = \underset{(0.1183)}{4.1623} - \underset{(0.0311)}{0.0299}YG, \quad R^2 = 0.008.$$

Among the initial hypotheses that evolved from the results of the analysis is one that involves the nature of the data set. The Murphey equation was estimated from data on cattle ranging in class and quality from Canner and Cutter cows to Prime steers. Other analysts have suggested the USDA formulation would not necessarily be expected to "fit" a more homogeneous data set (Kauffman et al., Stringer et al.).

The lack of homogeneity does not appear to be sufficient as an explanation of the unexpected results, however. Examination of the literature reveals analyses conducted on more homogeneous groups of cattle that estimated differences in cutout between yield grades well above the estimates generated by the Purcell-Nelson study (Dinkel et al., Henrickson and Monroe, Stringer et al., U.S. Meat Animal Research Center).

A second and possibly more productive hypothesis rests in the implications of the thickness of fat cover allowed in the cutout tests. Figure 1 demonstrates, via the slope of estimated functions, the change in total carcass cutout per yield grade and the associated maximum allowable fat cover based on data from several studies. If the maximum fat cover allowed at any one point is 0.5 inch or less, the slope of the estimated function is negative and is 3.0 or more in absolute value. Each function is labeled by the maximum fat cover at any one point allowed in the study and by the name of the major author(s). The notation "CC" is used to denote the research conducted at the U.S. Meat Animal Research Center, Clay Center, Nebraska (U.S. Meat Animal Research Center). The notation "USDA" refers to the implicit functional relationship consistent with the USDA's announced differences in cutability across yield grades (USDA 1968). The other studies are, by major author, Dinkel, Henrickson, and Stringer and the Purcell-Nelson analysis.

The alternative studies underlying the information shown in figure 1 were also analyzed via the following model:

(15) $$R_i = \beta_0 + \beta_1 D_{1i} + \beta_2 D_{2i} + \beta_3 D_{3i} + \beta_4 D_{4i} + \beta_5 Y_i + \beta_6(D_{1i}Y_i) + \beta_7(D_{2i}Y_i) + \beta_8(D_{3i}Y_i) + \beta_9(D_{4i}Y_i) + e_i,$$

where i = ith weighted observation; R_i = lean retail cuts as percentage of carcass weight for ith weighted observation; Y_i = yield grade of ith weighted observation; D_{1i} = 1 if i is from the Stringer data, 0 otherwise; D_{2i} = 1 if i is from the Henrickson data, 0 otherwise; D_{3i} = 1 if i is from the Dinkel data, 0 otherwise; D_{4i} = 1 if i is from the Purcell-Nelson data, 0 otherwise; e_i = error; β_0 = intercept for the Clay Center data; β_1 through β_4 = coefficients for intercept dummies for the Stringer, Henrickson, Dinkel, and Purcell-Nelson studies, respectively; β_5 = slope coefficient for the Clay Center data; and β_6 through β_9 = coefficients for slope dummies for the Stringer, Henrickson, Dinkel, and Purcell-Nelson studies, respectively.

Equation (15) thus incorporates both intercept and slope dummies for the five sets of

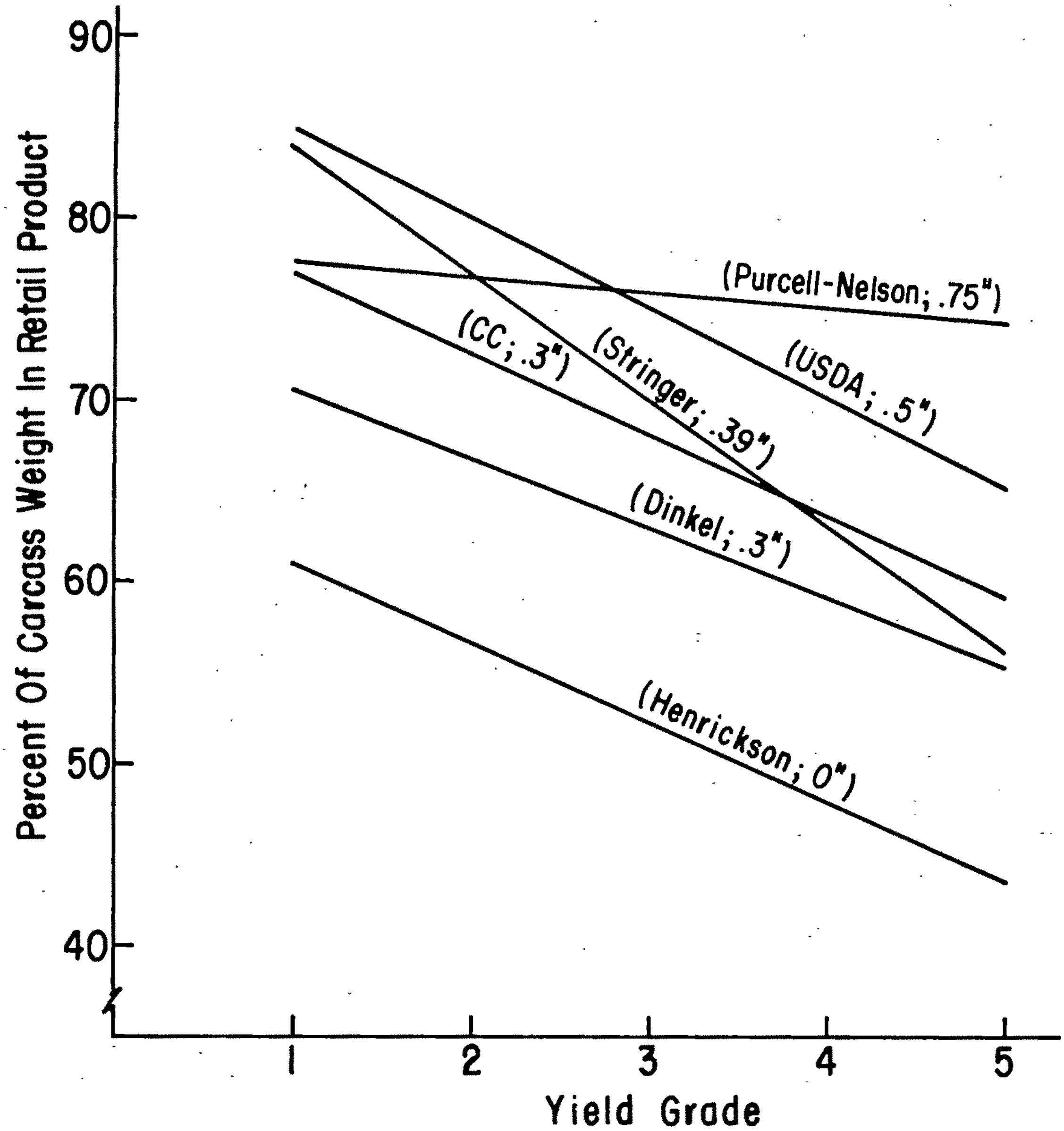

Figure 1. Estimated regressions for cutability on yield grade using mean observations from five different studies compared to the USDA relationship

data graphed in figure 1. With the Clay Center results established arbitrarily as a standard, the least squares estimates of the parameters in equation (15) provide numerical estimates of the differences in intercepts and slopes of the cutability equations across the five studies (U.S. Meat Animal Research Center). The function was estimated from a data set consisting of mean percentage of retail cuts as related to mean yield grades for all studies except the Purcell-Nelson study, where individual observations were used. Each mean was weighted by multiplying by the square root of the number of observations in the respective study. The results of the weighted least squares fit of the functional relationship are shown in table 4.

Several cautions are in order in evaluating table 4. First, the apparent level of quantitative measurement can be misleading. The data used in estimating the function do not justify accuracy to the extent implied by showing re-

Table 4. Regression of Retail Cuts as Percentage of Carcass Weight on Yield Grade

Parameter (β)	Estimated β	t-Statistic
β_0	81.176	—
β_1	9.732	5.327
β_2	−15.997	−14.895
β_3	−7.353	−10.519
β_4	−2.660	−4.471
β_5	−4.568	−32.169
β_6	−2.295	−4.314
β_7	0.243	0.897
β_8	0.811	5.651
β_9	3.761	21.248

F-value for regression = 1809.224
Error mean square = 1.018
R^2 = 0.975

sults to several significant digits. In both the Dinkel and Henrickson studies, yield grades were not shown. Consequently, yield grades were calculated using reported measurements on carcass weights, backfat thickness, and area of the ribeye. The kidney and heart fat data were not reported and were estimated by the authors from marbling scores and quality grades as suggested by USDA standards.

Second, the total number of carcasses analyzed differed across the studies. There were forty-two mean observations from a total of 1,123 head in the Clay Center data (U.S. Meat Animal Research Center). In the Henrickson data, at the other extreme, a total of six means with six observations per mean were available. The observations were weighted to insure statistical soundness of the estimation procedure, but the range of the various measures in the data sets could have been affected by the number of observations.

The results in table 4, therefore, should be treated as approximations of how the different studies would have compared if such comparisons had been designed into the studies. The studies had other, if somewhat related, objectives and generated data on carcass cutability as part of the analyses.

Table 5 records the "net" intercepts and slopes derived from equation (15) for each study along with the maximum allowable fat cover used in the respective studies. The USDA guidelines, which call for a change of 4.6% in actual product per yield grade, are based on a maximum fat cover of 0.5 inch at any one point on the cuts from the chuck, round, loin, and rib, 0.25 inch elsewhere. No attempt was made to test directly whether the net parameters recorded in table 5 are significantly different from each other. Examination of the t-statistics in table 4 indicates whether the estimates from the different studies are significantly different from those based on the Clay Center data.

The functions in figure 1 and the results shown in tables 4 and 5 support the hypothesis that the allowable fat cover will influence relationships between cutability and yield grade. Given the physical characteristics of the beef carcass, the results are not surprising. The better carcasses (yield grade 1's and 2's) often have a fat cover that exceeds 0.75 inch at only a few points. Retail cuts from these carcasses receive little trimming and may carry a fat cover less than 0.75 inch (and the related 0.5 average cover). Conversely, the cuts from low cutability carcasses (yield grade 4's and 5's) are often trimmed back to meet the requirement of 0.75 inch cover at any one point and carry the maximum allowable fat cover. The cuts from the 4's and 5's thus carry a fat cover that is weighed with the cut and included in the weight of the "lean retail cuts." The result is an increase in the weight of cuts from the 4's and 5's relative to the cuts from the 1's and 2's. The slope of the linear cutability function is decreased as a result.

The level of fat cover allowed also is a factor in the second surprising result of the

Table 5. Net Intercept and Slope Estimates For Five Studies

Study	Maximum Fat Cover Allowed at Any One Point on Retail Cuts (inches)	Net Estimated Regression Parameters	
		Intercept	Slope
CC	0.30	81.176	−4.568
Henrickson	0	65.179	−4.325
Dinkel	0.30	73.823	−3.757
Stringer	0.39	90.908	−6.862
Purcell-Nelson	0.75	78.516	−0.807

Source: derived from table 4.

analysis—the low R^2's. The smaller the fat cover allowed, the more homogeneous will be the resulting set of measurements (weights) on the lean retail cuts. For given sample sizes, a regression equation will "fit" the more homogeneous data better and the R^2 statistic will be larger.

The Research Needs

The results reported herein are not presented as the final answer. They constitute a beginning in terms of motivating more research on cutability. Many research efforts on cutability exist in the available literature. Some of the more recent efforts have been directed toward developing a cutability relationship incorporating variables not included in the USDA equation. The recent effort by Kauffman and his colleagues incorporated marbling score into a cutability equation. Whatever the purpose, the analyses that have been conducted are characterized by two important similarities. First, in an effort to exercise experimental control, most tests have been conducted under conditions approaching "laboratory control." Second, trim has been very close ranging from complete removal of all surface and intermuscular fat to leaving no more than 0.5 inch of surface fat at any one point. Many of the experiments have allowed a fat cover at any one point of 1 centimeter (0.39 inch) or less.

Interaction with industry personnel suggests the allowable fat cover on retail cuts varies across producing firms and by type of buying institution. A fat cover of up to 0.75 inch at any one point is reportedly commonplace in the rapidly increasing boxed-beef method of distribution. Given variability in cutting practices, cutability equations developed from experiments with the allowable fat cover held constant will have limited applicability to industry decision makers. Research designed to treat the allowable fat cover on the final retail cuts as a controlled variable and to establish its statistical and economic importance is needed. A review of past studies suggests that the estimated slope coefficients in cutability equations will be comparable in magnitude when the allowable fat cover at any one point is less than 0.5 inch. The results of the analysis reported herein suggest estimated slope coefficients will be substantially different when the allowable fat cover at any one point moves up to 0.75 inch. Given the direct relationship between the magnitude of the slope coefficient and value differences between yield grades, this area merits further investigation.

A related phenomenon also appears to need further investigation. As the allowable fat cover changes, the per carcass yield of edible fat varies. The trim from a carcass is usually divided into categories such as 50-50 trim (50% lean) and 75-85 trim (at least 75% lean) and brought into estimates of value differences by yield grades. But the edible fat is ignored in the value estimates. During periods when the slaughter mix includes a relatively high percentage of cows and nonfed animals, the edible fat trimmed from fed beef carcasses becomes valuable as an input to ground beef. During 1975, with relatively high levels of cow and nonfed slaughter, yield grade 4 carcasses periodically traded at price levels above yield grade 2 carcasses of comparable weight and quality grade.

Summary and Conclusions

The move to required yield grading offers significant potential as a means of increasing pricing efficiency in the beef-marketing system. However, it is also one of the changes that continues to attract vigorous opposition. Much of the opposition emerges from the packers who express concern over increased costs of grading. Perhaps more important is the varying interpretation of the applicability of current yield grade standards under industry operating conditions.

Analysis of the data from cutability tests on 118 beef carcasses suggests the applicability of current yield grades may in fact be limited to rather specific industry practices. Fat cover on the retail cuts from the 118 carcasses was allowed to range up to 0.75 inch at any one point, the normal practice for the breaking plant in which the tests were conducted and well within the tolerances in the USDA's IMP Series 100. When alternative measures of cutability were regressed on yield grade estimates of the slope parameter were negative but 1.15 or less in absolute value. This compares with a value of 4.6 reported by the USDA as the expected change per yield grade in percent of lean retail cuts from the total carcass. Other studies with relative close fat cover tolerances, 0.5 inch or less at any one

point, generate estimates closer to the 4.6% figure.

If the move to required yield grading is to facilitate increased pricing efficiency in the beef-marketing system, the yield grade standards must meet the dual requirements of broad use and applicability. Given the results of this analysis, it would appear that meeting these requirements will require several developments.

First, additional research to clarify the relationship between fat cover tolerances and the change in cutout of retail cuts per yield grade must be completed. Varying and controlled levels of fat cover tolerances should be designed into the research to provide direct estimates of the influence of fat cover on functional relationships between cutout and yield grade. If possible, the research should be conducted in the same industry environment in which the yield grades must be used.

Second, and related, more information should be disseminated on what the industry operator can reasonably expect when using yield grades to buy or sell in his operating environment. Continued publication of a 4.6% change in cutout of retail cuts per yield grade damages the credibility of the grades to the entrepreneur who argues he never realizes this type of differential. Acknowledging the 4.6% differential will hold only for "closely trimmed cuts" leaves modification and adaptation of this norm to the individual entrepreneur. The result can be an array of interpretations that does little to move the industry toward the standardized pricing base needed for increased pricing efficiency.

Third, it appears that an attempt to modify the yield grade standards to include the value of edible fat is needed. Theoretically, the yield grade 2 carcass is more valuable than the yield grade 4 carcass of comparable weight and quality grade. During 1975 the increased ratio of cow and nonfed slaughter to fed slaughter bolstered the value of edible fat trimmed from the fed carcasses. This helped precipitate prices for the yield grade 4 carcass that periodically moved above prices for the yield grade 2's and 3's. Either incorporation of the value of edible fat into estimates of value differences across yield grades or explanations of the somewhat atypical price relationships would boost credibility and support applicability of the yield grades.

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An Economic Evaluation of Alternative Peanut Policies

W. L. Nieuwoudt, J. B. Bullock, and G. A. Mathia

Three alternatives to the current peanut-price support, acreage-allotment program are considered. A linear programming framework is used to compare the effects of these policies on geographic location of peanut production, producer and consumer surplus, treasury costs, and value of allotments. Peanut production would expand in all areas except Texas under less restrictive production constraints. The largest expansion would be in Georgia and Alabama. Some version of the target price plan is considered to be a likely compromise program.

Key words: peanuts, policy, prices.

Peanuts are one of the few U.S. farm products receiving government price supports that have not been placed under the target price support legislation. The current peanut policy stems from the Agricultural Act of 1949 that established a minimum national acreage allotment of 1.6 million acres. Peanuts are supported between 75% and 90% of parity via a loan program, and peanuts not sold for edible use at the announced support price are acquired by the Commodity Credit Corporation (CCC).

Peanuts are not storable for long periods of time without refrigeration. Consequently, the CCC has disposed of its stocks by selling peanuts in the export market or for crushing purposes at prices considerably below acquisition prices. Peanut yields have increased more rapidly than edible use of peanuts leading to increased purchases by the CCC. This, coupled with depressed edible oil and meal prices during the late 1960s and early 1970s, led to rising treasury costs of the peanut program. Treasury costs in 1971 were $97 million (USDA 1974). As a result, the U.S. Department of Agriculture has proposed that peanuts be included in the target price legislation along with other agricultural programs. The peanut industry has so far successfully delayed efforts to scrap the existing program. However, efforts to change the program are likely to continue.

Peanuts are primarily produced in three areas of the United States: North Carolina-Virginia, Texas-Oklahoma, and Georgia-Alabama-Florida. The comparative advantage of growing peanuts differs among these areas due to cropping alternatives. Thus, policy modifications could have more impact on peanut producers in some areas than in others.

The purpose of this paper is to evaluate the effects of alternative peanut-price support policies on the geographic location of peanut production, farm income by regions, consumer and producer surplus related to peanuts, market prices of peanuts, and treasury costs. The analysis is based on costs and prices existing in 1973. The present policy is compared with the following alternatives: (*a*) free market, (*b*) 25% reduction in allotments, with peanuts grown on allotment acres supported at 16.2¢ per pound, and (*c*) prices supported at 15¢ per pound on 75% of current allotment acreage with no acreage restrictions or price supports on peanuts produced in excess of the reduced allotment. Comparisons are made between allotments that are transferable and nontransferable in alternatives (*b*)

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and (*c*). Policy alternative (*c*) is a version of the target price plan proposed by USDA.

Analytical Framework

Programming Model

A linear programming model of the Duloy-Norton type was developed to determine the aggregate and regional impact of alternative policies (Duloy and Norton). The model incorporates negative-sloping product demand curves and positive-sloping labor supply functions with an allowance for producer risk aversion. The model includes fifty-nine resource situations in seven states: North Carolina, Virginia, Georgia, Alabama, Florida, Texas, and Oklahoma. Resource areas included in the analysis account for 97.8% of the current peanut acreage in the United States. The programming matrix contains 578 rows and 1,447 variables.

The complete programming model for the competitive case where consumer and producer surplus are maximized can be expressed as follows:[1]

$$(1) \quad \max Z = [X'W(A - 0.5BWX)] - [C'X] - [L(K_1 + 0.5K_2L)] - \left[\sum_{i=1}^{7} \phi_i (X'\Omega X)^{1/2}\right].$$

The first term measures total welfare, which is the integral of the linear product demand function $P = A - BWX$, where W is a diagonal matrix of average yields and X is a vector of aggregate acres.

The production costs are deducted in the second term ($C'X$), where C is a vector of production costs. Opportunity cost of labor is deducted in the third term, which is the integral of a positively sloping linear supply function $R = K_1 + K_2L$, where R is a vector of wages per hour and L is a vector of hours.

Costs associated with risk are deducted in the last term, where Ω is a variance-covariance matrix of gross activity returns and ϕ_i is an aggregate of risk aversion coefficients of all farms in the ith production area. Variances and covariances of gross income were calculated separately for each area because of agronomic and crop mix differences.

[1] A tableau format of this type of program is presented in Hazell and Scandizzo. The mechanics of this model have been discussed in previous issues of this *Journal* (Hazell and Partasarathy, Hazell and Scandizzo, Simmons and Pomareda). Thus, only a brief outline of the model is presented here.

Structure of Demand

National demand elasticities were taken from various sources (Brandow, Hildreth and Jarrett, Jellema, USDA 1966). For some crops, such as corn, elasticities were calculated as weighted averages of direct human and derived livestock demands. National demand slopes were based on the following elasticities: soybeans −1.17, wheat −0.24, corn −0.27, barley −0.21, cotton −0.23, grain sorghum −0.90, hay (Alabama) −0.36, sorghum hay −0.36, and alfalfa hay −0.36. Exports and imports of all crops except peanuts are assumed to remain constant at existing levels.

The magnitude of the objective function solution (equation (1)) is affected by the size of the elasticity coefficients used. However, the relative magnitudes of the objective function among program alternatives would not be affected greatly. Thus, the magnitude of elasticities is not of major concern here since the purpose of the analysis is measurement of relative impacts of program alternatives.

Regional demands for all products except peanuts are highly elastic since their share of national production is small and supply outside the region is responsive to price changes. Regional demand slopes were derived from national demand slopes using a procedure suggested by Kutcher. The estimated regional demand elasticities (at 1973 production and prices) are about four times larger than national demand elasticities.[2]

The demand for peanuts has three components, namely, edible, crushing, and export. Estimates of demands for edible and export uses of peanuts were derived from secondary sources. The crushing demand was estimated directly. According to previous studies (Badger and Plaxico; Shafer, Nichols, and Branson; Reagan; Song), the demand elasticity for edible peanuts is about −0.25.

The export demand elasticity was estimated by the approach outlined by Johnson using demand and supply elasticities in the rest of the world. This procedure yielded an estimate of export demand elasticity for U.S. peanuts of −32.

A demand curve for crushing peanuts (linear in original values) was estimated by least squares regression using data for the period 1951–73 as follows:

[2] In all policy experiments with the programming model, the solutions obtained with the estimated elasticities were compared with solutions of a fixed price demand specification for all products other than peanuts.

$$(2) \quad P_{cr} = 0.375 + \underset{(5.0)}{1.457}P_{co} - \underset{(1.9)}{0.6147}Q_c + \underset{(3.3)}{0.001367}I, \qquad R^2 = 0.76,$$

where P_{cr} = price of peanuts for crushing (cents per pound), P_{co} = cottonseed price (cents per pound), I = disposable income per capita (dollars), and Q_c = crushed peanuts per capita (pounds). t-ratios are shown parenthetically.

The price flexibility of crushed peanuts at mean levels is estimated at −0.24. The price elasticity is probably larger in absolute value than −4.2 (the inverse of the price flexibility) since cottonseed and soybeans are substitutes for crushing peanuts.[3] The positive income coefficients can be explained by the fact that peanut oil is used for high quality salad or cooking oil.

Labor Supply

Separate regional labor supply functions for each month were built into the model. Labor constraints for any one month can be relaxed by hiring more labor at increasing wages as specified by the labor supply function. Seasonal and regional supply elasticities incorporated in the programming model are taken from Glover and from Tyrchniewicz and Schuh. Labor supply elasticities used for the Southwest were 1.25 for May to June and 2.12 for July to October. For the Southeast, including North Carolina-Virginia, labor supply elasticities of 1.03 for May to June and 1.75 for July to October were used.

Monthly labor available in each state was limited to the average monthly employment (regular labor) during the year. The supply of regular labor was assumed to be perfectly elastic at the minimum wage of $1.50 per hour up to the average employment level. Beyond this point, labor supply is assumed to be characterized by the above elasticities. Information on high school and college vacations was used to adjust the constant terms of supply functions. The opportunity cost of labor, i.e., area under the labor supply function, was deducted in the objective function. This is a nonlinear constraint that was linearized according to the method described by Duloy and Norton.

[3] A price elasticity is equal to the inverse of the price flexibility, only when all cross elasticities are 0 (Jellema). Song reported crushing demand elasticities between 9 and 26, but his results were significant only at the 50% level.

Risk, Production, and Cost Data

Price and yield risks are included in the model to account for year-to-year variability about the income levels reflected in the budgets. The risk component of the model is an effort to account for the realities of dynamics within the context of a static programming model. This study does not exploit the power of the Duloy-Norton model with respect to analysis of the risk aversion behavior of producers. The risk component of the model is used to improve the descriptive capacity of the model. No effort is made to study the risk behavior of producers or to incorporate the specific risk characteristics of alternative programs.[4]

Variance-covariance risk matrices are based on gross incomes per acre of the three main peanut-producing areas for the years 1967–72.[5] Variance-covariance matrices are approximated using the mean absolute deviation method described by Hazell and Scandizzo.

The more important peanut-producing counties in each state are included as separate resource situations. Other counties are pooled into homogeneous resource areas for each state based on soil and other characteristics. With the aid of soil maps and agronomic expertise, land considered suitable for peanut production was programmed in the model. A comparison of actual peanut allotment acreages to the total potential peanut acreages (shown in brackets) is as follows: North Carolina—165,405 [474,106], Virginia—102,000 [123,107], Alabama—197,000 [423,725], Georgia—507,490 [981,121], Florida—55,000 [117,178], Oklahoma—116,350 [330,000], and Texas—311,000 [689,600].

Detailed crop budgets were obtained for the three main producing areas of North Carolina-Virginia, Georgia-Alabama-Florida, and Texas-Oklahoma. These budgets were supplemented with information on relative magnitudes of cost items contained in other budgets (Freeman, McArthur, Strickland and Harwell, USDA 1966). The program was formulated to account for differences in small and large farms (Georgia-Alabama) and irrigation and dryland crops (Texas-Oklahoma). Allowances were made for nitrogen fixation by

[4] Income variability is likely to vary between programs, e.g., farmers would expect lower price variability under a price-support program than under a free market arrangement. However, the programs are assumed to have a neutral effect on risks of producers.

[5] Trend was eliminated from gross income per acre data.

Table 1. Comparison of Actual Plantings with Model Solutions

	Actual	$\phi = 0$	$\phi = 1$	$\phi = 2$	$\phi = 2.5$	$\phi = 3$
	1,000 acres					
Soybeans						
North Carolina	405	255	284	332	249	215
Georgia	524	793	769	666	769	807
Corn						
North Carolina	558	708	678	595	562	571
Georgia	1,221	885	928	1,062	1,103	1,102
Alabama	381	354	354	342	342	329
Cotton						
North Carolina	174	174	174	210	325	351
Georgia	322	404	404	370	225	184
Grain sorghum						
Oklahoma	79	32	1	1	1	1
Texas	1,229	1,383	1,349	1,349	1,315	1,315
Sorghum hay						
Texas	349	192	226	226	260	260
Wheat						
Georgia	107	93	74	77	77	83
Oklahoma	454	464	495	492	492	481
Alfalfa						
Oklahoma	152	186	186	186	186	196
Hay						
Alabama	195	136	136	148	148	161

peanuts and soybeans. A value for grazing was assigned to crops such as wheat in Oklahoma. Average yield data for fifty-nine resource areas obtained from crop-reporting offices were included for the three years (1971–73).

Model Results

Base (1973) cropping acres compared with model estimates, applying risk aversion values of $\phi = 0$, 1, 2, 2.5, and 3, are shown in table 1.[6] A value of $\phi = 0$ implies that producers are neutral to risk, and higher values of ϕ indicate that producers are more risk averse. Squared simple correlations between actual and predicted crop acres of state totals are, respectively, 0.864, 0.888, 0.937, 0.916, and 0.899.[7]

[6] To save space, crop acres are presented in table 1 only for those crops that changed with different ϕ values. Peanuts and tobacco came in at the maximum of their acreage allotments and were not affected by different ϕ values because of relatively high shadow prices on allotments.

[7] Little significance is placed on the value of ϕ selected. It is used here as a method of fine-tuning the predictive ability of the model. A premium was placed on accuracy, although the differences between several of these correlations are probably not statistically significant. A value of $\phi = 2$ produced the most consistent set of predictions when compared with actual production. Hazell and Partasarathy comparing alternative demand specifications, reported that $\phi = 1.5$ and 2.0 provided the best description of cropping patterns and prices of short cycle crops in Mexico. Simmons and Pomareda favored $\phi = 0.5$ for export crops and $\phi = 1.0$ for all crops.

Base crop prices (1973) are compared with dual prices as generated in the model in table 2. Squared correlation coefficients between base and dual prices for $\phi = 0$ and $\phi = 2$ are, respectively, 0.971 and 0.980.[8]

Dual wages generated by the model are presented in table 3. The wage rates increase to \$3 per hour (first column) in July and August because tobacco, a labor-intensive crop, is harvested in August.

Shadow prices on the present peanut acreage allotments, presented in table 4 (column

[8] A dual price is the shadow price of that segment on a demand function that is selected in the optimum solution (Egbert and Kim). A dual price thus provides a better estimate of the "true price" as determined in the optimum solution than the primal price that is calculated *ex post* when demand curves are segmented into steps.

Table 2. Base Prices (1973) Compared with Endogenously Generated Prices

Crop	Base[a]	$\phi = 0$	$\phi = 2$
Soybeans	5.722	5.327	5.407
Wheat	3.323	3.424	3.505
Corn	2.50	2.45	2.54
Cotton	0.589	0.517	0.533
Grain sorghum	2.27	2.17	2.22
Alabama hay	46.9	63.04	57.7
Sorghum hay	32.0	46.8	44.0
Alfalfa hay	48.0	44.6	45.35

[a] Cotton price is ¢/lb., hay prices are \$/ton. All other prices are \$/bu.

Table 3. Dual Wages of Model Solution

Month	North Carolina, Virginia, Georgia, Alabama, Florida	Oklahoma, Texas
	$/hour	
May	2.56	1.83
June	2.16	1.71
July	2.49	1.66
August	3.06	1.50
September	1.63	1.76
October	1.81	2.43

2), measure the annual per acre economic rent on peanut allotments to farmers. Shadow prices are consistent with observed rental values of allotment leases.[9] The shadow prices reported in table 4 are weighted averages of the fifty-nine resource areas included in the model.

The high shadow price (in cents per pound) in Georgia indicates that this state has a comparative advantage in peanut production relative to other areas. Peanut yields per acre in Georgia are about the same as in the North Carolina-Virginia area, but yields of alternative crops such as corn and soybeans are lower in Georgia.

The lowest allotment rent is for dryland peanuts in Texas (table 4). Shadow prices (cents per pound) in North Carolina are close to that of Virginia because peanuts are grown on either side of the common boundary between the two states. Slightly higher peanut yields and lower returns on alternative crops yield relatively high shadow prices on Oklahoma dryland peanuts.

[9] In policy experiments with the programming model, $\phi = 1$ was adopted for North Carolina-Virginia and $\phi = 2$ was used for all other states because peanut acreage appears to be sensitive to higher ϕ values in alternative policy solutions when the risk neutral case is compared with risk averse solutions.

Comparison of Current Program with Alternative Programs

Simulation of crop production patterns under the existing peanut program is now compared with model simulation solutions of alternative policies. Tables 5 and 6 show explicit estimates of several dimensions of program impacts. However, the relative magnitude of these estimates across programs is of more significance than the absolute levels. For example, the current program has an estimated treasury cost of $35 million and an estimated social cost of $67 million for the 1973 crop year (table 5, column 1). No claim for the precision of these estimates is made. However, the consistent estimation procedures used across policy alternatives should provide a good measure of the relative impact each alternative has in the various dimensions considered.

Social cost is measured in dollars of goods foregone because of a nonoptimum output. The reader is referred to Tweeten and Tyner for a more detailed discussion of social costs and to Marshall for a discussion of producer and consumer surplus.

Free Market Solution

This policy is simulated by using the maximization of producer and consumer surplus from

Table 4. Shadow Prices on Peanut Allotment Based on Model Solutions Compared with Observed Annual Allotment Rental Values

Area	Shadow Price	Allotment Rental Value[a]	Shadow Price[b] (¢/lb)	Allotment Peanut (acres)
	$/acre			
North Carolina	84.4	85	3.63	165,405
Virginia	100.6	90	3.72	102,000
Georgia	150.6	80–180	6.16	507,490
Alabama	77.9	n.a.	3.92	197,000
Florida	172.5	n.a.	6.63	55,000
Texas irrigation	83.2	45–65	3.92	111,200
Texas dryland	13.5	25	1.30	199,800
Oklahoma Southwest irrigation	142.4	125	4.32	32,000
Oklahoma dryland	70.1	65	4.34	84,350

[a] Rental values are based on the judgment of peanut experts (private communications) in different states. Land rent is excluded.
[b] Calculated by dividing the shadow price in $/acre by the state weighted average peanut yield.

Table 5. Comparison of Model Results for Alternative Peanut Policies

Element of Analysis	Current Program (1)	Free Market (2)	Reduce Allotments 25% with Support Price at 16.2¢ per Pound: Nontransferable Allotments (3a)	Reduce Allotments 25% with Support Price at 16.2¢ per Pound: Transferable Allotments (3b)	Reduce Allotments 25% with Support Price at 15¢ per Pound, Unrestricted Production Permitted at Free Market Prices: Allotments Not Transferable (4a)	Reduce Allotments 25% with Support Price at 15¢ per Pound, Unrestricted Production Permitted at Free Market Prices: Allotments Transferable (4b)
Price (¢/lb.)						
Edible	16.2	13.0	16.2	16.2	15.0	15.0
Crush	16.2	12.1	16.2	16.2	11.9	12.0
Export	16.2	13.3	16.2	16.2	13.1	13.2
Sales (mil. lbs.)						
Edible	1,840	1,917	1,840	1,840	1,874	1,874
Crush	569	638	101	101	707	661
Export	585	1,915	305	305	2,122	1,982
Seed/feed	127	127	95	95	127	127
Peanut acreage (1,000 acres)	1,454	1,945	1,091	956	2,094	1,967
Peanuts (mil. $)						
Consumer surplus	602	644	597	597	640	637
Producer surplus	265	286	199	231	324	325
All products (mil. $)						
Treasury cost	35	0	8	8	4	7
Allotment capital loss[a]	0	461	185	185	246	246
Producer surplus	753	719	716	756	747	783
Social cost	67	0	85	46	26	0

[a] Capital loss is an upper bound except for policies (3a) and (3b).

peanuts as the objective function of the model. This leads to the same result as a competitive market framework. A free market policy would lead to a 34% expansion in peanut acreage from current levels. This increase is due largely to an expansion of peanut production in the Georgia-Alabama-Florida area (table 6, columns 1 and 2). An increase in peanut acreage of 81% in this area gives some idea of these states' comparative advantage in peanut production.

By contrast, peanut acreage in Texas is reduced considerably. Peanut production in Oklahoma increases, demonstrating that although peanut yields are lower in Oklahoma than in the Southeast this state has a comparative advantage in peanut production. Peanut production expands in North Carolina and remains about the same in Virginia. The expansion in peanut production in the Southeast is accommodated largely through a reduction in area planted to soybeans.

Endogenously generated free market peanut prices in edible, crushing, and export markets were estimated to be about 3¢ per pound lower than base prices (table 5, columns 1 and 2).[10] Most of the increased production would be exported. Treasury and social costs of the free market solution are 0.[11]

Abolishment of allotments may entail a loss to farmers because allotments currently can be leased or sold. However, producers will not lose the full allotment rental value. The loss to producers is represented by the difference between the support price and free market price that is estimated to be 3.2¢ per pound (table 5). In states where rental values exceed 3.2¢ per pound, the difference between the rental rate and 3.2¢ is an addition to land rent. The value of land suitable for peanut production is then expected to increase in these areas.[12] The

[10] Price differences reflect grade differences because only the larger peanuts are exported.

[11] In contrast to a free market solution, producer surplus was maximized in an alternative solution (not presented) by equating marginal revenues of edible, crushing, and export demand to marginal cost of peanut production as determined in the program. Predicted peanut acres were about the same as under the current allotment program, but producer surplus and social cost increased substantially compared to the current program.

[12] Allotment value is excluded from land values in this context. It is also realistic to assume that differences in current allotment

Table 6. A Comparison of Estimated Crop Acres under Alternative Policies

	Current Program (1)	Free Market (2)	Reduce Allotments 25%, Allotments Not Transferable: No Open-End Production (3a)	Reduce Allotments 25%, Allotments Not Transferable: Open-End Production Permitted (4a)
	1,000 acres			
Soybeans				
Virginia	77	77	77	77
North Carolina	244	319	378	263
Georgia	769	500	871	500
Florida	124	85	135	85
Alabama	491	366	510	367
Oklahoma	51	40	68	40
Corn				
Virginia	173	188	199	166
North Carolina	596	554	607	572
Georgia	1,069	906	972	923
Florida	173	150	175	150
Alabama	342	347	374	348
Cotton				
North Carolina	297	214	194	250
Georgia	262	289	385	257
Alabama	0	0	0	0
Oklahoma	120	120	120	120
Grain sorghum				
Oklahoma	1	1	9	7
Texas	1,349	1,503	1,379	1,434
Sorghum hay				
Texas	226	263	261	261
Wheat				
Georgia	74	50	74	50
Alabama	0	0	0	0
Oklahoma	495	433	496	433
Alfalfa				
Oklahoma	186	175	186	175
Hay				
Alabama	148	144	146	144
Peanuts				
Virginia	102	87	77	110
North Carolina	165	216	124	218
Georgia	508	937	381	952
Florida	55	117	41	117
Alabama	197	320	148	319
Oklahoma	116	199	87	199
Texas	311	70	233	179
Tobacco				
North Carolina	116	116	116	116

possible rental loss to farmers in the free market solution is estimated at $92.2 million if gain in land rent is considered. If this is capitalized at 20% because of present uncertainty concerning continuation of the allotment system, capital loss to producers is estimated at $461 million.

Producer surplus, measured at base prices for all products except peanuts, falls slightly under a free market policy compared to the current program from $753 million to $719 million (table 7). Producer surplus in Georgia falls by only $4 million, in Oklahoma it remains the same, and in Florida it increases (table 7, columns 1 and 2) because of an expansion in peanut production.[13]

rental rates between counties are largely attributed to differences in land quality. Any input factor, however, with a positive supply captures a rent.

[13] It is important to test the sensitivity of policy solutions regarding alternative demand specifications. In an alternative model specification, consumer and producer surpluses of peanuts were

Table 7. Regional Producer Surplus for All Crops under Alternative Policies

State	Current Program	Free Market	Reduce Allotments 25% with 15¢ per Pound Support Price: Allotments Not Transferable	Reduce Allotments 25% with 15¢ per Pound Support Price: Allotments Transferable	Reduce Allotments 25% with 15¢ per Pound Support Price, Unrestricted Production at Free Market Prices: Allotments Not Transferable	Reduce Allotments 25% with 15¢ per Pound Support Price, Unrestricted Production at Free Market Prices: Allotments Transferable
	million $					
North Carolina	240	231	236	225	234	237
Virginia	44	37	41	33	40	41
Georgia	216	212	199	253	225	243
Alabama	66	58	62	50	61	69
Florida	27	30	25	39	31	34
Texas	85	77	82	74	80	79
Oklahoma	74	74	71	81	76	80
Total	753	719	716	756	747	783

The switch to a free market for peanuts would lead to a 15% reduction in peanuts grown in Virginia and about a 75% reduction in Texas. Peanut production would expand the most in Georgia and Florida.

Twenty-five Percent Reduction in Allotment Acreage

This program considers that allotments for individual farms are reduced by 25%, while peanut prices are kept at base levels. The purpose of such a program is to reduce treasury cost since no cost is incurred on edible peanuts, which comprise about 60% of the total production. By reducing allotments by 25%, treasury costs decline by 75% to $8.5 million.

If allotments are not transferable between production areas, producer surplus from peanuts declines by $66 million or 25%. However, producer surplus of all crops declines only by $36 million when all prices are kept constant (table 5, columns 1 and 3a). The smaller decline in total producer surplus is due to an expansion of other crops on land released from peanut production. The reduced peanut acreage was largely replaced by soybeans in the southeastern states including North Carolina (table 6, column 3a). "Capital loss" as a result of smaller allotments is estimated at $185 million. Producers lose the full rental rate plus land rent from peanut production on 25% of their allotments. According to table 7 (column 3a) producer surplus in all states falls. The social cost of $85 million for this policy is higher than that of the present program because of smaller acreage allotments.

If allotments are assumed to be transferable in the above program, a regional shift in peanut production would occur.[14] Farm income increases relative to the present level because peanuts move to areas with a comparative advantage in peanut production (table 7, column 4).[15] Although peanut production is reduced, the social cost of $46 million (table 5) for this policy is smaller than that of the current program because allotments are transferable. The estimated free market price for allotments is 5.6¢ per pound with this alternative. This compares with 5¢ per pound if the current program were continued but allotments were made freely transferable. The reduction in allotments leads to higher allotment rental values but lower land rents.

maximized assuming that prices of all other products are fixed. Predicted peanut acres for both cases are remarkably similar. The model in which all demands except peanuts are assumed perfectly elastic predicts a smaller decline in peanut acreage in Texas and a smaller expansion in Oklahoma.

[14] Peanut acreage allotments are currently transferable within county borders. The transfer, however, occurs on a yield basis, ensuring that total production remains the same. For example, if one acre allotment is transferred from a farm with a 1,500 pound yield of peanuts per acre to a farm with a 3,000 pound yield, the latter farm is entitled only to one-half an acre of allotment.

[15] Income from the sale of allotments is not included. Hoover and Efstratoglou Todoulos discuss how owners and renters are affected when transfers are permitted.

Target Price Plan

In this program, acreage allotments of individual farms are reduced by 25%. This acreage would be sufficient to meet domestic edible needs. Farmers would receive a target price of 15¢ per pound on peanuts produced under allotments. This program allows for unrestricted production in excess of the reduced allotment that would not be eligible for price supports.

This program will require the creation of some agency with monopoly power in selling peanuts for edible uses if users of edible peanuts are to pay 15¢ per pound for peanuts. Users of edible peanuts will otherwise purchase nonsupported peanuts at a lower price. This would lead to treasury costs for this program that are much higher than those shown here. This is a requirement of this program that apparently has not received much attention.

With a 15¢ per pound target price on allotment peanuts and unrestricted production sold in the free market (without support), peanut acreage expands 44%. Exports increase about threefold. Expansion in most states is similar to that predicted under the free market policy alternative, except that peanuts are "protected" in states with a comparative disadvantage, such as in Texas (table 6, column 4a). The 15¢ support price on the allotment acreage is a subsidy that acts through the marketing mechanism, stimulating peanut production above the free market level (table 5, columns 2 and 4a). Generated export and crushing prices of 13.1¢ and 11.9¢ per pound are similar to those of the free market solution (table 5, column 4a). These prices also correspond to the 15¢ target price and 12¢ floor price plan recently suggested by the USDA.[16]

Producer surplus from all crops declines by only $5 million compared to the present allotment system (table 5, column 4a). The small decline in producer surplus is due to an expansion in peanut production and the maintaining of a higher price in the inelastic edible market. Producer surplus increases in Georgia, Oklahoma, and Florida but falls slightly in the other states (table 7, column 4a).

The treasury cost of $4 million is less than the current program because allotments are reduced, and the social cost of $26 million is less than for the current allotment program due to unrestricted production. "Capital" loss as a result of smaller allotments and low support price is estimated at a maximum of $246 million. As explained for the free market policy, the increase in producer surplus from expansion in peanut production is not included in this number.

The target price plan would result in expanded peanut production in all areas except Texas. Peanut production in Texas declines by more than the 25% allotment reduction. Some areas of Texas would choose not to use their allotment if this program were implemented. Total peanut production under the target price plan would be about the same as for the free market alternative.

If allotments are transferable, predicted peanut acres are almost identical to that of a free market policy. Producer income is $2 million higher than that of the current program, and the social cost of $9 million is relatively small because of freedom in production and transferable quotas. The higher support price is simply an income transfer to farmers. The estimated free market price of allotment rental values is 1.9¢ per pound for this program alternative, which is equal to the difference in the support price (15¢ per pound) and the weighted average of export and crushing prices (13.1¢ per pound).

Conclusions

Three alternatives to the current peanut policy have been evaluated: (*a*) a free market alternative, (*b*) a 25% reduction in allotments with prices supported at 16.2% per pound, and (*c*) a target price plan where allotments are reduced by 25%, and peanuts produced on allotment acres are supported at 15¢ per pound; production in excess of allotment is permitted but receives no price support.

The "most desirable" program depends on the weights attached to the various impacts of alternative programs. None of the programs is clearly "best" in all dimensions. Policy makers and affected producers will have to decide which of the alternatives (including those not evaluated here) is most desirable given the realities of the political constraints.

Producers are most concerned about producer incomes and potential capital losses associated with allotments. Policy makers are likely to be most concerned about levels of treasury costs and to a lesser degree about

[16] During the middle of 1975, the USDA suggested a 15¢ target price on 75% of acreage allotments with a 12¢ floor price on unrestricted production.

social costs of alternative programs. The free market alternative is clearly most desirable from an economic point of view if income distribution problems are ignored. However, producers are likely to oppose strongly this alternative because of the sizeable capital losses involved and because of its potential effects on relocation of peanut production. The reader is referred to Tullock for an interesting discussion about the problems of capital losses caused by terminating or reducing government programs.

A 25% reduction in allotments with no open-end production may be attractive to policy makers since it reduces treasury costs. However, it is politically unattractive because it further limits producer choices and also has higher social costs than the current program. Peanut producers are likely to oppose this program because of reduced income plus capital losses in reduced allotments.

The target price plan greatly reduces treasury costs and social costs. It increases producer surplus and has very little effect on total farm income relative to the current policy. Capital losses from reduced allotment values are only about 53% of what they would be if a free market alternative is selected. Thus, some version of the target price plan appears to be a likely compromise policy.

This study has the limitations of being a comparative statics analysis of a dynamic problem. Further work is needed to evaluate the effects of program changes on farm size and the structure of the peanut-processing industry. These analyses were beyond the scope of this study.

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Estimating the Influence of Service Quality on Transportation Demand

Marc A. Johnson

Following a theoretical justification for considering service quality as a demand determinant based upon conventional derived demand analysis, an empirical procedure is developed for estimating the response of demand and modal selection probability to changes in service quality. The estimation technique suggested is similar to that used in the measurement of hedonic price indices, permitting a subjective evaluation of quality factors by shipping managers. An empirical demonstration suggests that transport demand responsiveness to transport service quality is inelastic for country grain elevators.

Key words: modal selection probability, service quality, transportation demand.

An argument often heard in Interstate Commerce Commission railroad abandonment hearings is that deterioration of railroad service quality has discouraged traffic sufficiently to cause line enterprise failure. Sensitivity of transportation demand to variations in service quality can be empirically tested. If transportation demand truly is sensitive to service quality, then (*a*) transport price elasticity estimates ignoring service quality will be biased and misleading, (*b*) simple traffic forecasting techniques will generate unreliable results, and (*c*) measurement of this sensitivity will provide a basis for adjustment of service standards to more effectively and efficiently serve shipping customers.

Empirical work with freight transportation demand is new enough that its chief value lies in developing a stock of methodological and statistical experience. This article offers a method for estimating the influence of transportation service quality upon transportation demand. The method is demonstrated empirically for grain shipments from country elevators. The empirical analysis illustrates the method. Further empirical experience with service quality elasticities is required before these parameters can be used confidently to improve traffic-forecasting procedures and to evaluate optimal service standard adjustments.

Perle attempted to estimate short-run, own, and cross-price elasticities of demand for railroad and motor carrier services using time-series data. Poor statistical results led Perle to conclude that price behavior provides neither a sufficient nor major answer to intercarrier competition. Perle recognized the potential influence of nonprice characteristics of movement and service but only as longer-term determinants of secular change associated with intermodal competition.

Subsequent theoretical contributions suggest the short-term significance of nonprice, transportation characteristics. Craig developed a behavioral model for transportation mode selection using price and service quality characteristics jointly. Managers measure attributes of each mode by levels of anxiety and select the mode that minimizes anxiety.

Kolsen developed a managerial utility model for selecting transportation modes involving price-quality combinations. Quality of transport service is added at a cost, and users are willing to pay higher prices for higher service quality. Service quality attributes are valued subjectively. Profit maximizing managers seek to equalize marginal subjective value with marginal cost of quality increments.

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A useful notion inherent in both the behavioral and quasiutility approaches to derived demand is implicit valuation by shippers of an array of service quality alternatives, whether monetary valuation is directly measurable or not. This notion suggests an approach to service quality elasticity estimation that is applicable where dollar costs of incremental service standards are not readily identifiable.

Market research in several European countries has revealed that shippers do recognize relative service quality attributes between modes (Bayliss). Service attributes that have been shown to influence modal choice are certainty of delivery time, speed, and product safety. However, Bayliss concludes that while market research reveals which quality characteristics are perceived to have value the approach lacks the ability to compare relative intensities of influence. Consequently, one may hear shippers complain of poor service quality, while relative capabilities of alternative modes are insufficient to cause a change in firm shipping patterns.

Empirical attempts have been made to estimate the probability that a firm will select a particular mode (Bayliss). However, modal selection probability models have not given broad attention to service quality characteristics. Typically, the influence of only physical movement characteristics is considered, such as commodity value per unit, consignment weight, and movement distance.

There appears a need to expand transportation demand and modal selection probability models to consider nonprice determinants treated in conceptual approaches and revealed in market studies. Following a brief theoretical justification for considering service quality as a demand determinant based upon conventional derived demand analysis, an empirical procedure is developed for estimating the response of demand and modal selection probability to changes in service quality. The technique is designed to estimate the quantitative influence of quality factors upon freight transportation demand, even when some of the quality factors can be evaluated only subjectively by shipping managers. A demonstration of the procedure for outbound railroad shipments of grain from Michigan country elevators serves to illustrate the use of the technique and to estimate first approximations of service quality elasticities for grain movements.

Theoretical Model

Freight transportation is an input to commodity production for which value is derived from the demand for final products at specific locations and times. Each transportation input for movements to a particular location can be described as a bundle of many rate and service quality characteristics. Service quality is an aggregate term referring to the bundle of nonprice characteristics of transportation inputs that influence their usefulness in the production process. Examples include transit speed, product safety, and service reliability. Individual service quality attributes may substitute for price characteristics when shippers select transportation modes. Service quality characteristics may be built explicitly into models of derived demand for railroad and motor carrier services, similar to the manner in which price is conventionally treated.

Assume a short-run production function of any firm producing a particular commodity of the general form

$$(1)\quad y = f(x_i, x_j | x_p) \quad \text{for } i = 1, \ldots, n, \text{ and } j = 1, \ldots, m,$$

where y = output quantity of the commodity produced, x_i = quantity of variable plant input i, x_j = quantity of transport service of mode j, and x_p = quantity of composite durable plant input. Transportation inputs (x_j), in units of tons or ton-miles moved per period, inject time and place utilities into goods and services produced by the firm. Assuming a competitive product market and factor markets that are either competitive or regulated to provide the firm with no control over input prices, the solution of necessary profit-maximizing conditions for the unknown input quantities provides definitions of derived demand functions for variable plant and transportation input flows:

$$(2)\quad x_i = d_i(p, r_i, r_j) \quad \text{and} \quad x_j = d_j(p, r_i, r_j),$$

where p = product price, the r_i's = variable plant factor prices, and the r_j's = effective transport prices. The quantity demanded of each input is dependent upon the output price and all factor prices.

Effective transportation prices include more than published transport rates. Effective prices are total unit costs incurred by users of transportation inputs. Examples of nonrate costs are the inventory costs associated with goods in transit, the cost of storing safety

stocks as insurance against unreliable service, and the costs of uninsured damage and loss. Effective transportation price for mode j may be defined as the published freight rate (r_{jp}) plus costs associated with an array of s service quality characteristics (r_{jq}). The nonprice consumption cost (r_{jq}) is dependent upon the levels of service quality characteristics (q_{jk}, $k = 1, \ldots, s$) offered by mode j. Thus, effective transport price for mode j appears as

$$(3) \qquad r_j = r_{jp} + r_{jq}(q_{j1}, \ldots, q_{js}).$$

Substituting the effective transport price definitions in equation (3) into the input demand functions in equation (2) reveals that total freight service demanded from mode j is determined by the magnitudes of product price, plant factor prices, published transport rates, and costs of using service of particular quality levels:

$$(4) \quad x_j = d_j[p, r_i, r_j(r_{jp}, q_{j1}, \ldots, q_{js})].$$

The rate of change in quantity of transport service demanded from mode j as own effective price (r_j) changes is $\partial x_j / \partial r_j$. The rate of change in effective transport price as service quality attribute k changes is $\partial r_j / \partial q_{jk}$. Thus, the rate of change in quantity demanded as service quality attribute k changes, operating through the effective price mechanism, is

$$(5) \qquad \frac{\partial x_j}{\partial q_{jk}} = \frac{\partial x_j}{\partial r_j} \frac{\partial r_j}{\partial q_{jk}}.$$

Service quality elasticity of demand equals this rate of change in demand multiplied by the ratio of quantitative quality and demand levels (q_{jk}/x_j). Similarly, the rate of change in the quantity of transport service demanded from mode j as service quality characteristic k of mode g changes is

$$(6) \quad \frac{\partial x_j}{\partial q_{gk}} = \frac{\partial x_j}{\partial r_g} \frac{\partial r_g}{\partial q_{gk}} \text{ for } j, g = 1, \ldots, m.$$

Cross service quality elasticity of demand equals this rate of change multiplied by q_{gk}/x_j.

Empirical Models

Theoretical results suggest that service quality changes influence the quantity of modal service demanded by a shipper firm through the effective price mechanism. Direct estimation of derived demand functions for freight service would require quantitative measurements of attributes associated with individual service inputs and costs of consumption accompanying these service levels. The latter category of information is difficult to quantify, increasingly so at finer levels of disaggregation. Indirect estimation involving measurement of the relationship between quantities of service demanded of a particular mode and levels of service quality characteristics reveals implicit shipper valuation of transportation performance. This result suggests the use of an econometric procedure similar to that used by Griliches to measure hedonic price indices.

Two types of demand relationships are composed for use in answering different types of questions. First, ordinary derived demand functions express total quantity of services demanded of a particular mode as a function of product and effective factor prices. Adjustments for individual firm and shipment characteristics are required to isolate service quality influences. These functions are useful for transportation companies seeking optimum service levels and for shippers and communities determining terms of trade in transport service contracting.

The general model of derived demand for transport services from mode j appears as

$$(7) \quad x_j = \alpha + \beta_1 p + \sum_i \beta_i r_i + \sum_j \beta_j r_{jp} + \sum_j \sum_k \beta_{jk} q_{jk} + \sum_l \beta_l w_l + \epsilon_j,$$

where x_j = quantity of service demanded of mode j, p = product price, r_i = price of variable plant input i, r_{jp} = published or market freight rate for mode j, q_{jk} = quantitative level of service attribute k for mode j, w_l = magnitude of firm or shipment characteristic l, and α and β = parameters. Regression coefficients measure the isolated influence of associated variables upon the level of transport demand. In particular, service quality coefficients (β_{jk}) are defined as in equations (5) and (6) of the previous section. Service quality coefficients measure the magnitude and direction by which the quantity of transport service demanded changes with marginal changes in service quality levels.

Second, modal selection probability functions relate quality of service to the probability that a randomly selected firm will use services of a particular mode. Again, isolation of service quality influences requires adjustments

for individual firm and shipment characteristics. Modal selection probability results can be used directly in traffic forecasting to determine the proportions of future traffic generations that will move by particular modes under particular service quality conditions.

The modal selection probability estimator incorporates the same independent variables with a different dependent variable form. Probability of selecting services from mode j (P_j) is limited to the range $0 \leq P_j \leq 1$. Direct estimation would force estimation with a limited dependent variable. Classical linear regression models are potentially inappropriate when the dependent variable is bounded and the error term is not. To remedy this problem, logit analysis may be used. The logit transformation may produce heteroskedasticity in estimate errors (Theil). Regression results should be checked for the presence of this problem.

The general model for the probability of selecting mode j appears as

$$(8) \quad \ln \frac{P_j}{1 - P_j} = \delta + \gamma_1 p + \sum_i \gamma_i r_i + \sum_j \gamma_j r_{jp} + \sum_j \sum_k \gamma_{jk} q_{jk} + \sum_l \gamma_l w_l + E_j,$$

where δ and γ = parameters. Regression coefficients measure the percentage of change in the ratio of the probability of selecting mode j to the probability of selecting some other mode caused by unit changes in demand determinants.[1] Partial elasticities of modal selection probability are obtained by multiplying the respective regression coefficients by the observed level taken by the attribute. Elasticities of modal selection probability represent the percentage changes in modal selection probability resulting from 1% changes in individual demand determinants. Independent variables are similar for the two types of models, assuming that relative and total modal service demands are subject to similar influences.

Some caution must be taken in selecting quality variables, functional form, and data base for estimating either model type. The essential weaknesses of passenger transportation demand studies have been summarized by Quandt in four categories. Three of these problematic categories are relevant in freight transport demand investigations. First, all important demand influences must be considered explicitly to avoid model specification error by omitting variables. Second, the proper functional form must be used in estimation to avoid model specification error by misspecified functional form. Finally, data should be disaggregated to the firm level, within a commodity class, to estimate coefficients useful in decision making.

A Demonstration: Grain Movements

Measurement of transport demand determinants is illustrated using a cross-section sample of total annual outbound grain shipments from individual grain elevator firms in Michigan. Average final product prices (or margins) and average variable plant input prices were considered constant across firms during the single sample year 1973. Normal seasonal product, input, and motor transport price fluctuations did not affect total annual shipment volumes. Published rail freight rates did not vary substantially during the period, leaving the variable to behave as a constant. Under these realistic price constancy conditions, the variation in quantity of railroad service demanded by the individual firms depends only upon the variation in service qualities of railroad and motor carriers.

Regression Models

Rigorous econometric tests for specification error by omitted variables were not possible with available data. However, a deliberate attempt was made to ensure the inclusion of all behaviorally relevant service quality characteristics. European market research studies have revealed that transportation mode selection is influenced by speed, product safety, and certainty of delivery time. Informal market research in Michigan confirmed the interest in these three characteristics. (This informal market research was conducted by the author during August 1973; results are reported by Johnson, pp. 122–24.) The delay in transport equipment delivery and the attention

[1] The dependent variable may alternately be expressed as log $(x_j/x_\bullet)$, where x_j is the quantity of freight services used of mode j and $x_\bullet$ is the total quantity of freight services used from all other modes. For a given observation, a new modal split $(x_j/x_\bullet)'$ resulting from a unit change in level of one service quality variable ($dq_k = 1$) may be obtained by first multiplying the coefficient of regression by the original modal split $(x_j/x_\bullet)$:

$$\frac{d \log(x_j/x_\bullet)}{dq_k} \frac{x_j}{x_\bullet} = \frac{d(x_j/x_\bullet)}{(x_j/x_0)} \frac{x_j}{x_\bullet} = d(x_j/x_\bullet),$$

then adding this resulting change to the original modal split:

$$(x_j/x_0) + d(x_j/x_0) = (x_j/x_\bullet)'.$$

by transportation sales representatives were also revealed to be important characteristics of transportation modes evaluated by Michigan grain shippers.

Two functional forms of the derived demand model were subjected to four specification error tests using sample data from grain elevators.[2] Linear and semilogarithmic (or index) functional forms of the derived demand model and the logit-linear form of the modal selection probability model were evaluated (Johnson). The linear functional form of the derived demand model yields biased error terms, indicating that regression coefficients would also be biased. The index (log-linear) functional form yields unbiased errors by the same tests and thereby unbiased parameter estimates. Heteroskedasticity is not present with either functional form for the sample. Subjection of the logit-linear form of the modal selection probability model to specification error tests suggests that this functional form will provide unbiased estimates without heteroskedasticity.

Data were accumulated from individual Michigan grain elevators using a mail questionnaire survey, distributed as the Michigan Freight Transportation Survey by the Michigan Department of State Highways and Transportation. The instrument measures movement and transport service quality characteristics of outbound grain shipments made by individual firms during the calendar year 1973. Characteristics of movement and service quality were measured for both motor and railroad modes.

The derived demand relationship for outbound grain shipments by railroad bears the log-linear form of

$$(9) \quad x_r = d_r(S, T, R, D, Sp_r, A_r, A_m, V_r, V_m, L_r, L_m, B),$$

where x_r = quantity of rail service demanded (tons), S = an indicator of firm size (1,000 bushel storage units), T = 1 if the firm owns a truck and 0 if not, R = 1 if the firm owns or leases a rail car and 0 if not, D = average distance of rail shipments (miles), Sp_r = average railroad speed (miles per day), A_r = availability of railroad cars (average days of delivery delay), A_m = availability of motor equipment (average days of delivery delay), V_r = number of promotional visits by railroad firms, V_m = number of promotional visits by trucking firms, L_r = average value of damage in rail transit per $1,000 value, L_m = average value of damage in truck transit per $1,000 value, and B = proportion of total shipments intended for railroad but diverted to trucks for lack of railroad cars. Individual regression coefficients are interpreted as proportional changes in the railroad service demanded due to unit changes in movement, firm, and service quality variables. Regression coefficients differ from theoretical results, equations (5) and (6), only in that the log-linear functional form provides proportional rather than absolute measures of response to demand determinants. Partial, own, and cross-service quality elasticities are obtained by multiplying regression coefficients by observed levels of associated service attributes.

The modal selection probability relationship uses the same explanatory variables with $\ln \frac{P_r}{1 - P_r}$ as the dependent variable for which P_r is the proportion of grain shipped by railroad from the individual observed firms during the sample year. When only railroad and motor transport modes are considered, the logit form becomes merely the logarithm of the ratio of rail to motor usage. Individual regression coefficients are interpreted as proportional changes in the ratio of railroad to motor carriage used with unit changes in quality variables. Partial, own, and cross-elasticities of modal selection probability are obtained by multiplying regression coefficients by observed levels of associated service attributes.

Quality of service variables are measured in their own natural units. The implicit price associated with railroad speed is the value of interest charges on inventory in transit. The truck speed counterpart could not be included, for most truck shipments were of less than one day. Implicit consumption costs associated with unexpected delays in railroad and motor equipment delivery are the sums of storage costs and inventory charges for each day products are held waiting for movement equipment. The number of promotional contacts serves to represent the degree of effort by transportation companies to please customers. The implicit values associated with

[2] These tests are RESET, RASET, KOMSET, and BAMSET developed by Ramsey. The first three are a battery of independent tests for biasedness of estimated errors produced by using the functional form being tested. These three tests are based upon regression on principal components, the nonparametric rank order test, and the Kolmogorov-Smirnov statistic, respectively. The BAMSET test indicates whether heteroskedasticity exists with the chosen functional form. This test is based upon Bartlett's M-statistic.

these variables include reduction in management requirements to establish rates and schedules of shipment. Damage and loss in transit is costly in terms of poor customer service, interest losses on money frozen in damage claims, and uninsured losses. Finally, the proportion of total shipments intended for railroad shipment but diverted to motor carriers for lack of railroad cars represents reliability of outbound service. The value of service reliability lies in efficient use of elevator storage facilities. Across firms, shipping patterns are likely to vary by individual firm characteristics of firm size and ownership of transportation equipment.

Regression Results

The index and logit equations are estimated using ordinary least squares regression with data from twenty grain elevator firms.[3] Regression on models incorporating all previously mentioned variables reveals the presence of multicollinearity. To enhance efficiency, estimators are formed with deletions of highly correlated variables. Where parameter estimates do not change substantially and where efficiency measures improve, valid interpretation with abbreviated models is possible.

Regression results for the derived demand relationship for railroad service are shown in the first equation of table 1. Influences of railroad promotional effort, truck damage, and delays in motor freight equipment delivery are removed from analysis due to high correlation among these variables. Variable deletion does not change the magnitudes of individual coefficients substantially. However, the standard error of the estimate was greatly reduced and the explanatory power of the model was enhanced, as related in the *F*-statistic. The quantity of railroad services demanded by grain shippers is significantly influenced by the firm size, the delay in delivery of railroad cars, and the magnitude of damage and loss in transit. An increase (decrease) in elevator size by 10,000 bushels of storage capacity results in

[3] A large portion of these data were used in testing for specification error in the choice of functional form. Independent data samples must be used to verify these results before using coefficients in demand prediction.

Table 1. Regression Results for Railroad Demand and Railroad Selection Probability Estimators

Demand Determinant	Railroad Demand	Railroad Selection Probability
Constant	11.0332	2.1350
	(1.5893)[a]	(0.9127)
Market distance	−0.0020	0.0029
	(0.0023)	(0.0014)
Storage capacity	0.0013	−0.0037
	(0.0005)	(0.0009)
Truck ownership	−0.3917	−1.2669
	(0.8206)	(0.5653)
Rail car leasing	0.7434	−0.3925
	(0.7577)	(0.4692)
Tonnage diverted to truck (%)	0.0029	0.0016
	(0.0035)	(0.0041)
Truck equipment delay		−0.4129
		(0.1565)
Rail equipment delay	−0.0562	−0.0007
	(0.0298)	(0.0201)
Damage by truck		−0.1894
		(0.1638)
Damage by railroad	−0.0125	0.0252
	(0.0054)	(0.0157)
Truck promotional effort	−0.0145	−0.0671
	(0.0360)	(0.0197)
Railroad promotional effort		0.5510
		(0.1342)
Railroad speed	−0.0043	−0.0294
	(0.0079)	(0.0054)
Standard error	0.9751	0.4664
$\bar{R}^2$	0.451	0.744
F	$F_{9,10} = 3.163$	$F_{12,7} = 6.626$

[a] Standard errors of coefficients are given in parentheses.

a 1.3% increase (decrease) in the quantity of railroad service demanded annually, *ceteris paribus*. Each day added to the average delay in receiving railroad cars causes grain shippers to demand 5.6% less railroad service annually, holding other influences constant. The isolated effect of an increase in railroad freight damage of $1 per $1,000 of shipment value is a decline of annual rail service usage by 1.25%.[4] Elasticities of railroad demand with respect to firm size and service quality characteristics are shown in table 2 for mean firm size and service quality levels.

Regression results for the modal selection probability model appear in the second equation of table 1. The model including all potentially influential variables appears useful. Variable deletion to enhance estimator efficiency is not possible because highly correlated variables appear to affect modal selection; variable deletion would probably bias remaining estimates.

Three movement and firm characteristics and four service quality characteristics appear to influence proportionate use of transport modes. For an increase (decrease) in the average distance to market of one hundred miles, the proportion of rail to truck shipment increases (decreases) by 29%, *ceteris paribus*. This may be explained as a rapidly declining substitutability of truck for rail service for longer distance distribution patterns.

Firm size and truck ownership affect the proportion of modal services used. Larger firms tend to place proportionally greater reliance upon motor carriage than do smaller grain handlers. As the elevator storage capacity increases by 10,000 bushels, the ratio of rail to truck shipment decreases by 3.7%, *ceteris paribus*. The influence of truck ownership upon the proportionate use of the rail mode is extreme in magnitude but strongly suggests that truck ownership by grain handling firms reduces proportionate use of rail transportation. These results may imply scale economies in truck ownership that allow larger firms to command a truck fleet.

Promotional effort by transportation companies appears to be important in selecting transportation modes. An additional contact by a trucking firm decreases the ratio of rail to motor usage by 6.7%, holding other influences constant. An additional contact by a railroad company will increase the ratio by 55%, *ceteris paribus*. Promotional contacts by railroad firms are few, and there may exist diminishing returns at higher levels of effort. However, at existing low levels of promotional effort, personalizing railroading may have high payoff from grain elevators.

Table 2. Elasticities of Railroad Demand with Respect to Firm Size and Service Quality

Demand Determinant	Mean Level	Elasticity
Firm size (1,000 bu. storage)	294.6	0.38
Rail equipment delay (days)	15.6	−0.88
Damage by railroad ($1/$1,000 shipment value)	14.4	−0.18

Other service quality results are less intuitively appealing. The faster is railroad service or the less reliable is delivery of trucking equipment, the smaller is the relative amount of railroad service used, *ceteris paribus*. The relative preference for slower service may indicate that the value of railroad cars as storage containers for shipments of undetermined destination exceeds the loss in inventory charges on grain owned during transit. Reasons for the inverse relationship between delay in motor equipment delivery and the ratio of rail to motor carriage used are unclear but may be related to multicollinearity. Elasticities of modal selection probability are shown in table 3 for mean levels of movement, firm, and service quality variables.

Conclusions

Statistical experience has been gained by demonstrating procedures for estimating derived demand and modal selection probability functions for grain movements. Regression results reveal that the index form of the derived demand relationship isolates the influence of several important railroad service demand determinants even with small samples of microeconomic data. Delay in railroad car delivery and damage in railroad transit appear to cause significant reductions in total annual volumes of grain shipments by railroad. The degree of demand responsiveness to these service qualities tends to be inelastic.

From the information on modal selection

[4] A strong conclusion cannot be made based upon this latter result. Motor carrier and railroad damage are highly related ($r^2 = 0.882$) in the test sample and the significance of the railroad damage influence depends upon the deletion of the truck damage variable from the model.

Table 3. Elasticities of Modal Selection Probability for Railroad Service[a]

Demand Determinant	Mean Level	Elasticity
Market distance (miles)	679.0	1.97
Storage capacity (1,000 bu. storage)	294.6	−1.09
Truck promotional effort (no.)	4.0	−0.27
Rail promotional effort (no.)	2.8	1.57
Truck equipment delay (days)	1.9	−0.78
Railroad speed (miles/day)	74.0	−2.17

[a] Elasticity of modal split with respect to truck ownership cannot be calculated for truck ownership is indicated by a binary variable.

probability elasticity estimates, it is inferred that the proportionate use of railroad transport to ship grain would be increased more than in proportion to increases in distance to grain markets. Grain elevator firms of larger size place relatively more importance upon motor carriage than do smaller firms. The relative proportion of rail to truck transport demand in the grain industry is highly positively responsive to the promotional effort by railroad firms and slightly negatively related to the promotional effort by trucking firms.

Market research and testimony before Interstate Commerce Commission line abandonment hearings have suggested that service quality has a major impact upon quantity of railroad service demanded and thereby upon line viability. Results of regression on the derived demand model support the notion that service quality does tend to affect railroad service demand but not to the extent previously suggested. The total quantity of railroad services demanded by grain shippers bears inelastic response to important service quality influences.

The difference between vocal complaint and action can be explained by the concept of economic action thresholds. In a transportation market with discontinuous opportunities, a shipper may be inconvenienced by relatively poor service of the railroad mode, while operating costs associated with poor service quality may not exceed the difference between published railroad and motor carrier freight rates. Given a particular firm output level, the less costly transportation mode may decrease service quality until the effective price of consuming services equals the effective price of the next least expensive mode. Only at this level of service deterioration will the shipper have reached an economic action threshold that causes a change in modes. However, aside from traffic diversion, an increase in the effective price of the least costly mode may raise marginal production costs of the shipper firm, discouraging some traffic.

More statistical experience with transportation demand estimation is required to verify estimates of service quality and modal split elasticities before using these parameters in transportation planning. Further studies with new data samples are recommended to derive independent estimates using knowledge of variable selection and functional form developed here as prior information. Also, empirical investigation of transportation demand for the movement of commodities other than grain is needed to expand knowledge of basic transportation market characteristics.

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A Model of Consumer Goods Characteristics

George W. Ladd and Veraphol Suvannunt

This paper derives and tests two hypotheses concerning characteristics of purchased consumer goods. One hypothesis states retail price paid is a weighted linear combination of a product's yields of characteristics, each weight being a marginal implicit price of a characteristic. The second hypothesis expresses consumer demand for a product as a function of income, product prices, and product's yields of characteristics. Statistical results are consistent with the hypotheses. One model used in this paper is the consumer goods counterpart to the model used by Ladd and Martin in studying prices and demands for input characteristics.

Key words: hedonic prices, product characteristics, quality.

In a study carried out nearly fifty years ago, Waugh concluded, "There is a distinct tendency for market prices of many commodities to vary with certain physical characteristics which the consumer identifies with quality, and the relation of these characteristics to prices may in many cases be fairly accurately determined by statistical analysis. If this generalization is accepted as true, it opens up a field in the theory of prices which has been practically untouched" (1929, p. 87). This paper deals with this "field in the theory of prices" by developing a model—the consumer goods characteristics model (CGCM)—that yields the two hypotheses that are the themes of this paper. These are: for each product consumed, the price paid by the consumer equals the sum of the marginal monetary values of the product's characteristics; the marginal monetary value of each characteristic equals the quantity of the characteristic obtained from the marginal unit of the product consumed multiplied by the marginal implicit price of the characteristic (theme 1), and consumer demand functions for goods are affected by characteristics of the goods (theme 2).

The CGCM looks upon a product as a collection of characteristics. Product heterogeneity arises because different products contain different kinds, different amounts, or both of various characteristics. CGCM is therefore useful for studying issues involving product heterogeneity such as product differentiation, quality, and grades and standards.

After developing the hypotheses stated in themes 1 and 2, all available statistical evidence is summarized. Then a number of applications are discussed. (Themes 1 and 2 refer to consumer goods. Two similar themes that apply to production inputs are discussed by Ladd and Martin.)

Theoretical Model

Products are wanted because of the utilities they provide. The utilities provided depend upon the product characteristics. Hence, the total amount of utility a consumer enjoys from his purchases of products depends upon the total amounts of product characteristics purchased. Let x_{0j} be the total amount of the jth product characteristic provided to the consumer by consumption of all products. Let x_{ij} be the quantity of the jth characteristic provided by one unit of product i. For example, x_{ij} might measure the length of an automobile, the presence or absence of an automatic transmission, or the amount of preparation time saved by using a TV dinner. Let q_i represent the quantity of the ith product consumed. Suppose we have n products and each of the first m product characteristics is provided by

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several products, but each product also provides a unique characteristic provided by no other product. Then total consumption of each characteristic can be expressed as a function of quantities of products consumed and of consumption input-output coefficients:

$$(1) \quad x_{0j} = f_j(q_1, q_2, \ldots, q_n, x_{1j}, x_{2j}, \ldots, x_{nj}) \text{ for } j = 1, 2, \ldots, m,$$

and

$$x_{0m+i} = f_{m+i}(q_i, x_{im+i}) \quad \text{for } i = 1, 2, \ldots, n.$$

The consumer's utility function is expressed as

$$(2) \quad U = U(x_{01}, x_{02}, \ldots, x_{0m}, x_{0m+1}, \ldots, x_{0m+n}).$$

Because each x_{0j} is a function of the q_i's and the x_{ij}'s,

$$(3) \quad U = U(q_1, q_2, \ldots, q_n, x_{11}, x_{12}, \ldots, x_{1m}, x_{21}, \ldots, x_{nm}, \ldots, x_{nm+n}).$$

It is assumed that the consumer can vary only the q_i's. The magnitudes of the x_{ij}'s are parameters to the consumer; their magnitudes are determined by producers.

The consumer is assumed to maximize equation (2) subject to the budget constraint

$$(4) \quad \sum_i p_i q_i = I,$$

where p_i is the fixed price paid for the ith product, and I is the consumer's fixed money income, that is, the consumer selects the values of the q_i that maximize the Lagrangian

$$(5) \quad L = U(x_{01}, x_{02}, \ldots, x_{0m+n}) - \lambda(\sum_i p_i q_i - I).$$

The consumer is viewed as selecting the combination of products that provides the combination of total product characteristics that maximizes utility. Choices of products are based on their different characteristics. Because the x_{0j}'s are functions of the q_i's, compound function (function of a function) rules for differentiating U must be used:

$$(6) \quad \partial L/\partial q_i = 0 = \sum_j(\partial U/\partial x_{0j})(\partial x_{0j}/\partial q_i) + (\partial U/\partial x_{0m+i})(\partial x_{0m+i}/\partial q_i) - \lambda p_i.$$

To assure a unique maximum, the Hessian of U is assumed negative definite and the bordered Hessian of L is assumed negative semidefinite.

The marginal utility of income is λ: $\lambda = \partial U/\partial I$. Substituting this expression into equation (6) and solving for p_i yields

$$(7) \quad p_i = \sum_j(\partial x_{0j}/\partial q_i)[(\partial U/\partial x_{0j})/(\partial U/\partial I)] + (\partial x_{0m+i}/\partial q_i)[(\partial U/\partial x_{0m+i})/(\partial U/\partial I)].$$

The marginal yield of the jth product characteristic by the ith product is $\partial x_{0j}/\partial q_i$, e.g., the amount of protein per pound of a particular steak. The marginal yield of the ith product's unique characteristic is $\partial x_{0m+i}/\partial q_i$. In the bracketed terms, $\partial U/\partial x_{0j}$ is the marginal utility of the jth product characteristic, and $\partial U/\partial I$ is the marginal utility of income. Their ratio is the marginal rate of substitution between income and the jth product characteristic. By equation (4), income equals total expenditure. Therefore, the bracketed term can be interpreted as the marginal rate of substitution between expenditure and the jth product characteristic, that is, as the (marginal) implicit or imputed price paid for the jth product characteristic. For convenience, write $(\partial U/\partial x_{0j})/(\partial U/\partial I) = \partial I/\partial x_{0j} = \partial E/\partial x_{0j}$, where E = total expenditure on all products. Assume each unit of each product supplies one unit of its own unique characteristic. Then, $\partial x_{0m+i}/\partial q_i = 1$, and equation (7) becomes

$$(8) \quad p_i = \sum_j(\partial x_{0j}/\partial q_i)(\partial E/\partial x_{0j}) + \partial E/\partial x_{0m+i}.$$

Equation (8) states theme 1.

Equations (4) and (6) provide a system of $n + 1$ equations in the $n + 1$ unknowns λ, q_1, $q_2, \ldots, q_n$, and the knowns $I, p_1, p_2, \ldots, p_n$, $x_{11}, x_{12}, \ldots, x_{nm+n}$. Solving these equations provides the maximizing values of λ and of consumption, say, λ^*, q_{1*}, $q_{2*}, \ldots, q_{n*}$. The effect of change in price p_s upon q_{r*} is given by the well-known expression $\partial q_{r*}/\partial p_s = -q_s \cdot \partial q_r/\partial I + S_{sr}$, where S_{sr} = the Slutsky-Hicks-Allen substitution term. Assume the producer of product u makes a small change in x_{uv}, while all other x_{ij}'s, all prices, and income remain constant.[1] By differentiating equations (4) and (6) with respect to x_{uv}, and manipulating, one obtains

$$(9) \quad \partial q_{r*}/\partial x_{uv} = -(1/\lambda^*) \sum_{i=1}^{n} (\partial U_i/\partial x_{uv}) S_{ir},$$

where $U_i = \partial U/\partial q_i$. The change in q_{r*} resulting from a change in composition of product u depends upon the effects of the change in

[1] Product u is a slightly different product after this change from what it was before the change. Before the change, the quantities of characteristics per unit of product u were $x_{u1}, x_{u2}, \ldots, x_{uv-1}, x_{uv}, x_{uv+1}, \ldots, x_{um}$. Afterwards, they are $x_{u1}, x_{u2}, \ldots, x_{uv-1}, x_{uv} + dx_{uv}, x_{uv+1}, \ldots, x_{um}$.

composition upon marginal utilities and upon substitution terms. Thus, the change in demand for product r as x_{ur} changes depends upon product r's complementarity or substitutability with other goods. Hence, the consumer's purchases of product r can vary even though his income and product prices remain constant, provided that producers vary at least one consumption input-output coefficient.

Assume that $\partial U_u/\partial x_{uv} > 0$ but $\partial U_i/\partial x_{uv} = 0$ for $i \neq u$, i.e., increasing the amount of characteristic v in product u increases the marginal utility of product u but leaves other marginal utilities unaffected. Then, from equation (9),

$$(10) \quad \partial q_{r*}/\partial x_{uv} = (-1/\lambda^*)(\partial U_u/\partial x_{uv})S_{ur}.$$

If products u and r are substitutes ($S_{ur} > 0$), increasing the value of x_{uv} reduces the demand for product r. If the two products are complements ($S_{ur} < 0$), increasing x_{uv} increases the demand for product r. Setting $r = u$ in equation (10) yields

$$(11) \quad \partial q_{u*}/\partial x_{uv} = (-1/\lambda^*)(\partial U_u/\partial x_{uv})S_{uu} > 0.$$

Equations (9), (10), and (11) provide the hypothesis stated in theme 2.

Comparison with Lancaster's Analysis

Recently Lancaster used the product characteristics concept in his activity analysis of consumer behavior. He formulated the consumers' utility maximization problem as (p. 21)

$$(12) \quad \max\ U(X) \text{ subject to } P'Q \leq I, \quad BQ = X, X \geq 0, \text{and } Q \geq 0.$$

X is a vector of quantities of characteristics, Q and P are vectors of quantities and prices of products, and B is the consumption technology matrix of input-output coefficients. The ith row of $BQ = X$ can be written as

$$(13) \quad \sum_j b_{ij}q_j = x_{0i},$$

where b_{ij} = the quantity of the ith characteristic in one unit of product j, and q_j and x_{0i} are as defined previously in CGCM. The rules for deriving the dual to this problem are discussed by various writers, among whom are Sengupta and Fox. Applying these rules leads to n dual constraints (one for each product) of the form

$$(14) \quad p_j \geq \sum_i b_{ij}z_i \text{ for } z_i \text{ unrestricted in sign.}$$

This corresponds closely to equation (8), since b_{ij} corresponds to $\partial x_{0i}/\partial q_j$ and z_i corresponds to the marginal implicit price of characteristic i. Lancaster did not derive equation (14) from his general activity analysis model. But he did derive equation (14) from a special expenditure minimizing linear program.

Others who have used the product characteristics concept without, however, developing themes 1 and 2 are Theil and the workers in the hedonic price index area (see Griliches, Adelman and Griliches, Dhrymes). These writers use the utility function equation (3). They are prevented from deriving themes 1 and 2 by their assumption that the magnitudes of the x_{ij}'s and the q_i's are determined by the consumer. The x_{ij}'s are treated here as parameters to the consumer and variables to producers. The consumer can decide how much of product i to buy; he cannot however decide the amount of each characteristic to be contained in or provided by one unit of product i.

Three reviews of Lancaster's model have recently been published (Hendler, Lucas, Ratchford). Lucas questions Lancaster's assumption of a linear consumption technology, equation (13). This criticism does not apply to CGCM; compare equation (13) with equation (1). Hendler discusses limitations arising from Lancaster's assumption that marginal utilities of all characteristics are nonnegative. We do not make this assumption; any $\partial U/\partial x_{0j}$'s in equation (6) may be negative. Both Lucas and Hendler seriously question Lancaster's assumption that utility depends only upon total quantities of characteristics and not upon their distribution among commodities. This criticism does apply to CGCM. Themes 1 and 2 can be derived from a variation of CGCM to which none of these three criticisms apply. Define t_{ij} as the total quantity of characteristic j obtained from total consumption of product i. Then $x_{0j} = \sum_i t_{ij}$. In this variation of CGCM, the arguments of the utility function are the variables x_{0j}'s and the ratios x_{0j}/t_{ij}'s. But since the x_{0j}'s are functions of the t_{ij}'s, the utility function can be expressed simply as a function of the t_{ij}'s. The statement of theme 1 derived from this model is exactly like equation (8) except that t_{ij} replaces x_{0j}. The statement of theme 2 is exactly like equation (9).

Empirical Tests

Equation (8) provides the hypothesis that for each product purchased by the consumer, the

price he pays can be expressed as the sum of the products of marginal yields of characteristics and ratios of marginal utilities. We have called these latter ratios marginal implicit prices. All of the data seen on yields of product characteristics are consistent with the assumption that $\partial x_{0j}/\partial q_i = x_{ij}$ = constant. Assuming this and assuming $\partial E/\partial x_{0j} = E_j$ = constant, equation (8) can be written as

$$(15) \qquad p_i = \sum_j x_{ij}E_j + E_{m+i}.$$

Regressing product prices upon product characteristics (as measured by x_{ij}) provides a test of the hypothesis that p_i is linearly related to the x_{ij}'s. If $\partial E/\partial x_{0j}$ is not believed constant, one might use

$$(16) \qquad p_i = \sum_j x_{ij}\beta_j + \sum_j x_{ij}^2 \beta_{jj},$$

and determine marginal implicit price, say, for characteristic h, as $\partial E/\partial x_{0h} = E_h = \beta_h + \beta_{hh}x_{ih}$. Hedonic price workers generally have used logarithmic equations ($p_i = \pi_j x_{ij}^{\beta_j}$) or semilogarithmic equations ($p_i = \exp(\Sigma x_{ij}\beta_j)$) to relate product prices to product characteristics. Neither of these forms is consistent with equation (8); they cannot be interpreted as relating product price to the sum of the products of marginal yields of characteristics and marginal implicit prices.

Dhrymes applies equation (15) to U.S. automobile prices. He found that a large proportion of the variance in U.S. automobile prices could be explained by a linear combination of automobile length, width, brake horsepower, number of cylinders, number of doors, and presence or absence of automatic transmission and power steering. Cowling and Cubbin found that a large proportion of variance in U.K. automobile prices could be explained by a linear combination of automobile characteristics.

Waugh (1928, 1929) estimated relations between wholesale prices of fresh vegetables and their characteristics. He collected data on wholesale prices and characteristics of individual lots of asparagus, tomatoes, and cucumbers. He regressed the ratio of the price of each lot to the average price of the product on measures of product characteristics and converted the regression coefficients into prices of product characteristics. For example, from his analysis of prices of asparagus, he concluded that (*a*) each additional inch of green color per stalk added 38.45¢ to the price of one dozen standard bunches, (*b*) each additional stalk per bunch reduced price by 4.6¢, and (*c*) each additional percentage variation in size of stalk decreased price by 0.76¢ per dozen standard bunches.[2] For asparagus and tomatoes he used a linear equation, like equation (15). For cucumbers, he used a nonlinear relation, like equation (16).

In these studies, the values of the x_{ij}'s were fairly easily determined, either by inspection or by studying manufacturer's specifications. We performed a more rigorous test of equation (8), more rigorous because the characteristics are not easily identified and measured. The linear form was used to relate annual average retail prices of thirty-one different meat, dairy, and poultry items to amounts of various nutritional elements they provided per pound.

Table 1 lists the thirty-one food items. Their national annual average retail prices per pound for 1969 and 1970 were obtained from U.S. Bureau of Labor Statistics reports. Amounts of sixteen different nutritional elements per pound of each food were obtained from Watt and Merrill. These sixteen elements and their units of measurement are identified in table 2.

Suppose that one's sample contains one observation on each of n products and these products contain m common characteristics, that is, each of the m common characteristics is possessed by two or more of the n products. Then it is not possible to estimate a separate price for each common characteristic and each product's unique characteristic because the number of coefficients to be estimated exceeds the number of observations. The number of observations is n but the number of coefficients is $n + m$, m coefficients for the prices of common characteristics plus n coefficients for the prices of unique characteristics. To handle this degrees-of-freedom problem, we imposed restrictions on the prices of unique characteristics. First, the prices of unique characteristics are assumed to be the same for every product. With the requirement that $E_{m+i} = E_{17}$ for all i, the following equation was estimated:

$$(17) \qquad p_i = \sum_{j=1}^{16} x_{ij}E_j + E_{17} + \epsilon_i \qquad \text{for } i = 1, 2, \ldots, 31.$$

In this form several pairs of the independent variables were highly intercorrelated. After eliminating one variable of each of these pairs

[2] Although equation (8) refers to retail prices and Waugh studied wholesale prices, his results are consistent with theme 1 because wholesale and retail prices are highly positively correlated.

Table 1. Thirty-one Food Items Used in Estimation

Item i
1. Round steak
2. Sirloin steak
3. Porterhouse steak
4. Boneless rump roast
5. Rib roast
6. Chuck roast
7. Hamburger
8. Beef liver
9. Veal cutlets
10. Pork chops
11. Loin roast
12. Pork sausage
13. Whole ham
14. Picnic ham
15. Bacon
16. Lamb chop
17. Frankfurters
18. Canned ham
19. Bologna sausage
20. Salami sausage
21. Liver sausage
22. Frying chicken
23. Chicken breasts
24. Eggs
25. Grocery fresh milk
26. Delivery fresh milk
27. Skim fresh milk
28. Evaporated milk
29. Ice cream
30. American process cheese
31. Butter

and eliminating other variables with small t-ratios, the results in the second and third columns of table 3 are obtained.

Next, the price of uniqueness was assumed to be a function of raw material source and the following equation was estimated:

$$(18) \qquad p_i = \sum_j x_{ij} E_j + E_i + \epsilon_i,$$

where $E_i = E_B$ for food items 1 through 8, beef; $E_i = E_V$ for item 9, veal cutlets; $E_i = E_H$ for items 10 through 15, pork; $E_i = E_L$ for item 16, lamb chops; $E_i = E_{PM}$ for items 17 through 21, processed meats; $E_i = E_P$ for items 22 through 24, poultry products; and $E_i = E_D$ for items 25 through 31, dairy products. Analysis of variance indicated that many of these E_i were not significantly different from each other.

Finally, the products whose prices of uniqueness were not significantly different from each other were grouped together, and the following equation was estimated:

$$(19) \qquad p_i = \sum_j x_{ij} E_j + E_i + \epsilon_i,$$

where $E_i = E_{18}$ for all items except veal cutlets and lamb chops, $E_i = E_{25}$ for veal cutlets, and $E_i = E_{32}$ for lamb chops. These results are presented in table 3. Equation (19) yielded a significantly larger value of R^2 than did equation (17) or (18). All three equations yielded significant values of R^2. Thus, all are consistent with theme 1. Results in table 3 were obtained by pooling data for 1969 and 1970 because results of an F-test for equality of two sets of coefficients did not reject the hypothesis that the coefficients were equal in the two years.

We interpret $\hat{E}_j$ in table 3 as estimated implicit prices paid by consumers in 1969–70 for the nutritional elements identified in the first column. For example, $j = 2$ identifies food energy measured in calories; $\hat{E}_2 = 0.026$ in equation (19) indicates the estimated implicit price of food energy was 0.026¢ per calorie. Suppose there was some cut of beef that was like sirloin except that it contained one hundred more calories of food energy and ten more grams of protein per pound. Equation (19) predicts that the price of this cut of beef would have been 19¢ per pound higher than the price of sirloin in 1969–70: 0.026(100) + 1.666(10) = 19.26.

Dhrymes and Cowling and Cubbin obtained negative coefficients for some automobile characteristics. Waugh obtained negative coefficients for some vegetable characteristics (1928, 1929); as mentioned earlier, he found a negative marginal implicit price of 4.6¢ for number of stalks per bunch. Negative marginal implicit prices are consistent with CGCM

Table 2. Nutritional welements and Their Units of Measurement

Nutritional Element j	Nutritional Element	Unit of Measurement of Nutritional Element (per pound)
1	Water	%
2	Food energy	cal.
3	Protein	g.
4	Fat	g.
5	Carbohydrate	g.
6	Ash	g.
7	Calcium	mg.
8	Phosphorous	mg.
9	Iron	mg.
10	Sodium	mg.
11	Potassium	mg.
12	Vitamin A value	I.U.
13	Thiamine	mg.
14	Riboflavin	mg.
15	Niacin	mg.
16	Ascorbic acid	mg.

Table 3. Estimated Equations for Implicit Prices for Nutritional Elements in Thirty-one Food Items, 1969–70

	Equation (17)		Equation (19)		
Nutritional Element j	Regression Coefficient $\hat{E}_j$	Absolute Value of t-ratio	Regression Coefficient $\hat{E}_j$	Absolute Value of t-ratio	Unit of Measurement of $\hat{E}_j$
2, food energy	0.022[a]	3.548	0.026	7.250	¢/cal.
3, protein	2.691	4.695	1.666	3.818	¢/g.
5, carbohydrate	0.017	0.059	0.074	0.404	¢/g.
8, phosphorous	−0.127	3.791	−0.077	3.080	¢/mg.
9, iron	−5.329	2.379	−1.539	0.886	¢/mg.
11, potassium	0.236	23.600	0.016	2.462	¢/mg.
14, riboflavin	26.197	2.740	11.085	1.550	¢/mg.
16, ascorbic acid	−1.718	2.657	−0.957	1.881	¢/mg.
17	−7.873	0.474	—	—	¢/lb.
18	—[b]	—	−8.307	0.779	¢/lb.
25	—	—	109.921	6.040	¢/lb.
32	—	—	67.270	3.246	¢/lb.
R^2	0.624		0.853		

[a] $\hat{E}_j$ is the estimate of E_j. Equation (19) has fifty degrees of freedom. For fifty degrees of freedom, critical levels of absolute values of t-ratios are 2.678 at 1% level, 2.008 at 5%, 1.658 at 10%, 1.300 at 20%, and 0.681 at 50%.

[b] Dash indicates not estimated.

and with observation. Some product characteristics are undesirable. Adding more of one of these characteristics to a product reduces its value to consumers. We do not know why $\hat{E}_8$ and $\hat{E}_{16}$, the marginal implicit prices for phosphorous and ascorbic acid, are negative. Two hypothetical explanations are (*a*) phosphorous and ascorbic acid impart an unpleasant taste, texture, or odor and (*b*) they are proxies for some characteristic that degrades taste, texture, or odor.

These four statistical studies are the only ones we know of that bear on theme 1. The results of all four are consistent with the theme.

The multiple regression method used in these studies is not the only available method for estimating prices of nutritional elements. The shadow prices in duals of programming models of human diets also provide estimates of implicit prices of nutritional elements (see Smith 1959, 1963 for discussion).

Equation (9) presents the hypothesis that consumer demand for a product is related to the characteristics of the product as well as to prices and income. Four studies have tested this hypothesis; all have confirmed it. In a study of demand for beer, Stone tested and accepted the hypothesis that ". . . if stronger, and to that extent better, beer is obtainable at a given price, then more beer will be drunk" (p. 180). Brems found that the ratio between registrations of new Fords and new Chevrolets was significantly positively related to the ratio of their brake horsepower. The Cowling and Cubbin study of the U.K. automobile market found automobile demand to be related to automobile characteristics. Harrington and Gislason found that retail sales of peaches were affected by peach color, retail sales of apricots were affected by color, defects, and hardness, and retail cherry sales were affected by ripeness of cherries. All four studies are consistent with theme 2.

Summary and Conclusions

The first theme of this paper is that for each product consumed, the price paid for the product equals the sum of the marginal monetary values of the product's characteristics. The marginal monetary value of each characteristic equals the product's marginal yield of the characteristic multiplied by the marginal implicit price of the characteristic. This theme is derived in three different ways: from Lancaster's analysis, in CGCM, whose assumptions are less restrictive than Lancaster's, and in a third model whose assumptions are less restrictive than those of CGCM. Results of all relevant statistical analyses are consistent with the theme. One practical use of this theme is in use of marginal implicit prices to evaluate grading schemes for consumer products. Ladd and Martin used a model similar to

CGCM to evaluate the present U.S. corn grading system.

The second theme of this paper is that consumer demands are affected by characteristics of goods. This theme was derived from CGCM and from another model. Results of statistical studies are consistent with this theme. One practical application of this theme is in product design. If the relation of consumer's purchases to product characteristics is known, a product can be designed to maximize profit by determining how much of each characteristic to put into the product. Dorfman and Steiner analyze the problem of optimal product design for a product having one variable characteristic. Ladd and Martin analyze the problem for a product having several variable characteristics.

CGCM has implications for the definition and measurement of product quality. It leads to the same conclusion that Southworth presented when he wrote, "Webster's first definition of 'quality' makes it synonymous with 'characteristic.' Quality meaning 'superior quality' is a derived or secondary meaning. Quality, then, need not be ordinal—good, better, best. It may only be different" (p. 1385).

Consideration of CGCM leads naturally to the idea that we measure a product's characteristics in order to measure its quality. In doing this we replace the idea of "product quality" by "product qualities" and measure "qualities" by measuring characteristics. This recognizes that it may not be possible to rank two similar products according to their quality. It may be that product A is of higher quality than product B according to one characteristic but of lower quality according to a second characteristic. Then all we can say is that A and B are of different quality.

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The Value of Frost Forecasting: A Bayesian Appraisal

A. E. Baquet, A. N. Halter, and Frank S. Conklin

The economic value of frost forecasts is estimated under various assumptions concerning prior information, accuracy of forecasts, and the shape of the orchard operator's utility functions. The frost protection decision process is simulated in the context of Bayesian decision making under uncertainty. The averaged seasonal values estimated per day per acre were \$5.39 for frost forecasts provided by the U.S. Weather Service, \$8.57 for perfect frost forecasts, \$4.73 for profit maximizers, and \$191.39 for completely ignorant decision makers. The methodology used has general application to determination of economic value of information under conditions of uncertainty.

Key words: Bayes, decision making, frost forecasts, information value, risk, uncertainty, weather.

Orchard production is highly vulnerable to weather effects, particularly from frost damage during a six-week period of flowering and bud development. From mid-March to mid-May, nighttime temperatures in Jackson County, Oregon, are likely to fall low enough to cause frost damage in pear orchards. The specific temperatures below which frost damage will occur depend upon several factors, including the development stage of the blossom from which fruit emerges (Washington State University).

Each afternoon during a frost season a temperature forecast is given by a meteorologist employed by the U.S. Weather Service, who lives in Jackson County for a two-month period during the frost season. The forecast is first issued at 4:00 p.m. over local radio and television stations. Temperature and dewpoint prognostications are given, along with a subjective prediction whether or not heater firing will be needed that night.[1] A revised forecast is given later in the evening. A telephone service is provided also, whereby the orchardists may call an unlisted number to receive the latest weather forecast directly from the meteorologist. The orchardists are faced with the decision of whether or not to protect their orchards each night during the frost season. Each orchardist may then use the forecast that has been given, along with his own feelings as to the accuracy of the forecast, any other information available, and his own attitude toward uncertainty in deciding whether or not to protect the orchard. If an orchardist has decided that protection will be needed, then how much protection he uses is determined for the most part by how much the forecasted temperature is below the critical temperature and the type of mechanical protection used by the orchardist. In Jackson County the major protection scheme involves orchard heaters (Bates, Lombard). Heaters will raise the orchard temperature 4° to 5° when approximately thirty-five are used per acre. Thus, if the temperature is forecasted to be 2° below the critical temperature, the orchardist may decide to light only half his heaters.

Although frost protection is but one phase of an orchard management process, the decisions made relative to it have a direct and significant economic effect on orchard production since, if the crop is lost to frost, the decisions pertinent to orchard operation for the rest of the season may have limited or no effect on current year production. Thus, fore-

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[1] Dewpoint influences the specific value of the critical temperature. Dewpoint is the temperature level below which moisture held in suspension in the air condenses in the form of dew or frost. When the dewpoint is above 32°, the moisture condenses to form dew and provides some protection against frost. Because there is no unanimity among orchardists as to the role the dewpoint plays in determining the specific value of the critical temperature, it was not included in this study.

cast information appears to have considerable economic value to orchardists. The funding of the forecasting services provided by the U.S. Weather Service is a continuing problem for this agency. The economic value of this information can have much to do with the level of funding, yet little effort has been expended on determining this value (Byerlee, Lave, Thompson). It is the intent of this paper to provide estimates of the economic value of frost forecast information under various assumptions concerning prior information, accuracy of the forecasts, and the shape of operator's utility functions. This paper views the frost protection decision process in the context of Bayesian decision making under uncertainty (Baquet, Byerlee, Byerlee and Anderson, Dillon, Halter and Dean).

Model for Evaluating Frost Forecast Information

A diagram of the simulation model used in evaluating frost forecast information is shown in figure 1. There are three major components shown in the diagram to be discussed in turn. These are the nightly frost protection decision, the simulated nightly weather conditions, and the accounting that determines the value of the frost forecast for that night.

Nightly Frost Protection Decision

The frost protection decision covers the center of the diagram from the monetary payoff table to the frost protection level. The payoff table shows the possible monetary gains from various frost protection actions (number of heaters lighted) for each possible state of nature (θ_k, where $k = 1, \ldots, 16$ temperatures from 21° to 35° and over). The payoff values are developed from expected values of the crop and harvest savings. The expected values of the crop are determined by the expected price and yield as well as the bud loss.

A utility function estimated for the individual orchardist is used to convert the dollar payoff table to the utility payoff table. This table is then multiplied by the posterior probabilities, $P(\theta_k|Z_j)$, to give the utility of actions given the forecast (Z_j, where $j = 1, \ldots, 16$). From this posterior utility table, the optimal action for each forecast is obtained, this action being the one with the highest utility for that forecast. The optimization is carried out using Bernoulli's principle to obtain the optimal action A^{**}_{ij}, or Bayes's strategy (Baquet, Bernoulli, Dillon):

$$(1) \qquad U(A^{**}_{ij}) = \max_i \ U(A_i|Z_j) = \max_i \ [\sum_k U(a_k)P(\theta_k|Z_j)],$$

where $U(A^{**}_{ij})$ = the utility value of the optimal action for each forecast (Z_j), A_i = the set of alternative actions, $i = 1, \ldots, m$, Z_j = the set of forecasts, $U(a_k)$ = the utility of the dollar payoff from an action for each state of nature k, and $P(\theta_k|Z_j)$ = the posterior probability of a state θ_k and a forecast Z_j, $k = 1, \ldots, 16$, and $j = 1, \ldots, 16$. After the forecast is given, the optimal action for that forecast from the Bayes strategy defines the level of frost protection to be followed, which together with the simulated temperature determines the bud loss for that night and so on.

Actual Nightly Temperature

Simulated temperatures for a particular night are determined by a random process described by the posterior distribution $P(\theta_k|Z_j)$; that is, a temperature is drawn at random from a probability distribution of the states of nature (θ_k) given for each forecast (Z_j).

Value of Frost Forecast

The third component of the diagram is the determination of the value of the forecast. In utility terms, this is the difference between the expected utility of the optimal action if one did not have the forecast and the expected utility of the optimal action with the forecast. While one can obtain this utility value $U(Z_j)$ for a forecast after it is given, of greater interest here is the $U(Z_j)$ value for the entire set of forecasts or in other words the value of the service itself for the entire frost season. In general, the $U(Z_j)$ is still the difference between the utility of the set of optimal actions given the forecasts, but the analysis is carried out before the forecast is given. Using available literature, let us develop this concept further (Baquet, Byerlee, Dillon, Halter and Dean, Harvey).

Suppose a choice has to be made between a set of actions, $A_1, A_2, \ldots, A_m$, where the ith action (A_i) has a set of uncertain consequences, $[a_k]$. Which a_k occurs depends on the state of nature that occurs. The states of na-

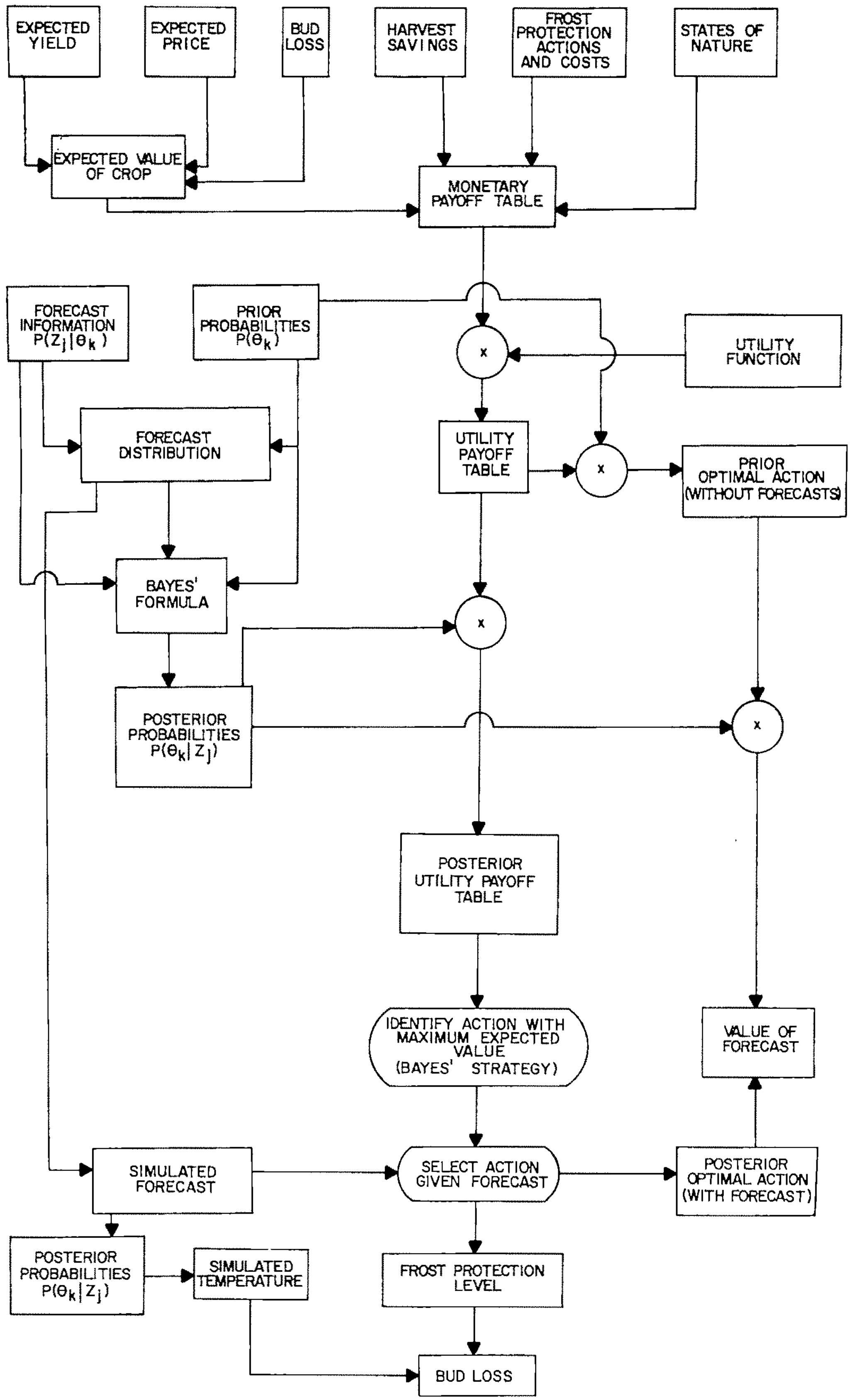

Figure 1. Flow diagram of simulation model used in the valuation of frost forecast information

ture follow the probability distribution $P(\theta_k)$. Thus, the uncertain consequences also follow the probability distribution $P(\theta_k)$. The consequence of a_k of A_i is a random variable, and a particular consequence a_k has a utility $U(a_k)$. In the case given here, the set of consequences $[a_k]$ are specified as gains or returns from the orchard's expected production potential.[2]

The expected utility of the ith action is

$$(2) \qquad U(A_i) = \sum_k U(a_k)P(\theta_k),$$

and the optimal action A^*_i is the one with the highest utility. The decision procedure, then, is to choose the action that has the maximum utility. This can be represented mathematically as

$$(3) \qquad U(A^*_i) = \max_i \ U(A_i) = \max_i \ [\sum_k U(a_k)P(\theta_k)].$$

A^*_i is the prior optimal action (without forecast) in figure 1.

Assume that a particular piece of information (Z_j) relative to the occurrence of state of nature (θ_k) is available to the decision maker at a cost of C. Given that the decision maker has knowledge about the conditional distribution of Z_j relative to $\theta_k(P(Z_j|\theta_k))$, Bayes's formula allows for revision of the prior probability distribution of $\theta_k(P(\theta_k))$ to obtain the posterior probability distribution $P(\theta_k|Z_j)$:

$$(4) \qquad P(\theta_k|Z_j) = \frac{P(\theta_k)P(Z_j|\theta_k)}{P(Z_j)},$$

where $P(Z_j) = \sum_k P(\theta_k)P(Z_j|\theta_k)$. This sequence of calculations is shown in the left upper center portion of figure 1. This posterior probability distribution was used in finding the Bayes strategy in the decision sequence described above.

We let A^{**}_{ij} ($i = 1, 2, \ldots, m$ actions, and $j = 1, 2, \ldots, n$ states) represent the optimal action for the jth forecast (Z_j). The Bayes strategy may be specified by the n-element vector:

$$(5) \quad \{A^{**}_{ij}\} = (A^{**}_{i1}, A^{**}_{i2}, \ldots, A^{**}_{ij}, \ldots, A^{**}_{in}).$$

The probability that each of these actions will be followed is the probability that the forecast Z_j will be given, i.e., $P(Z_j)$. The utility of the Bayes strategy $(U(\{A^{**}_{ij}\}))$ can be calculated as

$$(6) \qquad U(\{A^{**}_{ij}\}) = \sum_j U(A^{**}_{ij})P(Z_j).$$

The value of the set of forecasts in utility terms is

$$(7) \qquad U(\{Z_j\}) = U(\{A^{**}_{ij}\}) - U(A^*_i),$$

that is, the utility of the Bayes strategy minus the utility of the prior optimal act. Written into its component expressions and in terms of money, the utility value of the set of forecasts is given by

$$(8) \quad U(\{Z_j\}) = \sum_j [\sum_k U(a^{**}_k - C)P(\theta_k|Z_j) - \sum_k U(a^*_k)P(\theta_k|Z_j)]P(Z_j),$$

where a^{**}_k = the monetary outcome of the Bayes action, a^*_k = the monetary outcome of the optimal prior action, and C = the monetary cost of the information.

The term in square brackets is the utility value of a particular forecast. The utility value of a possible prediction set $\{Z_j\}$ is equal to the weighted average of the posterior value of the particular predictions, the weighting scheme being $P(Z_j)$. Thus, if

$$(9) \qquad U(\{Z_j\}) = \sum_j U(Z_j)P(Z_j)$$

is positive, the information is worth having. However, this is of little practical use, since decision makers or public agencies cannot transfer utility values in transactions with others. Thus, it is necessary to determine the monetary value of the set of forecasts.

The monetary value of the forecast is the maximum amount of money the decision maker could give up and remain as well off with the forecast as he would have been with just his prior information. In other words, the monetary value is determined by the dollar amount that, when subtracted from each cell of the dollar payoff table and converted to utility, yields the same expected utility as the optimal prior act.

The maximum amount that should be paid

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[2] Initially, we thought the payoff table should be in terms of dollar values of crop losses. This was based on the notion that before the frost season orchards have the potential for a full crop and then during the frost season some of this potential is lost. We were initially going to use the disutility of these losses. However, orchardists indicated that in regard to frost protection they do not think in terms of what is lost but rather in terms of what is saved, implying that there is only an expected production potential at the beginning of the frost season but that the actual potential develops during this period and whatever portion is saved by frost protection is a gain. Frost protection is viewed as a means for generating a high production potential by the end of the frost season.

by the decision maker is given by the value of C in equation (8) that makes $U(\{Z_j\}) = 0$. When $U(\{Z_j\})$ is equal to 0, the decision maker is as well off with just his prior information as he is with the additional information.

Empirical Data Used in the Application of the Simulation Model

The simulation model of figure 1 requires three types of data to make it operational. These are probability distributions, utility functions, and the monetary payoff tables. The model has been programmed for computer calculation and, given the data, the computer program provides the value of the frost forecasts for the total season and on a per-acre-per-day basis. The expected yields and prices and the utility functions used for this study came from orchardists in the Jackson County pear-growing area of Oregon. The probability distributions were derived from historical weather records for the U.S. Weather Service (U.S. Dep. of Commerce).

Probability Distributions

Temperatures have been recorded at selected unheated orchards during the frost season since 1957. Forecast data for an "average orchard" have also been recorded since 1957. The average orchard was selected for its ability to exhibit temperatures that are similar to the temperatures in the majority of the orchards in the county. Based on historical and current orchard temperature data from the average orchard site, the owner or manager of an orchard is expected to extrapolate the forecasted temperature from the average orchard to the expected temperature in their orchards.

Both the forecasted and recorded temperatures for the average orchard have been used in this study to determine the prior probability distribution $P(\theta_k)$ and the conditional probability distribution $P(Z_j|\theta_k)$ from the sixteen years of data available (Courson and Navarro). The conditional probabilities are given in table 1. There were 925 days covered by the records, of which 420 have recorded temperatures. On the remaining days, both the forecasted and actual temperatures were over 35°. Each cell in table 1 was determined by dividing the number of times a given forecast (Z_j) occurred by the number of times a specific state of nature (θ_k) occurred during the sixteen years of frost season data.

The ability of the forecaster to predict a temperature condition is independent of the absolute value of the actual temperature; thus, the $P(Z_j|\theta_k)$ values of table 1 are not dependent on the week or the month of the frost season when the prediction is made. Consequently, all temperature observations made during each frost season since 1957 are included in

Table 1. Conditional Probability Table $P(Z_j/\theta_k)$ of Forecast Temperatures and Recorded Temperatures, Jackson County, 1957–72

Forecasted Temperature (Z_j)	Recorded Temperature (θ_k)															
	θ_1	θ_2	θ_3	θ_4	θ_5	θ_6	θ_7	θ_8	θ_9	θ_{10}	θ_{11}	θ_{12}	θ_{13}	θ_{14}	θ_{15}	θ_{16}
	ND[a]	35°	34°	33°	32°	31°	30°	29°	28°	27°	26°	25°	24°	23°	22°	21°
Z_1 ND	0.97780	0.62500	0.05455	0.30357	0.25926	0.11765	0.05455									
Z_2 35°	0.00185		0.03030	0.01786	0.01852	0.02941										
Z_3 34°	0.00370		0.06060	0.01786	0.01852	0.02941										
Z_4 33°	0.00555			0.01786		0.05882	0.01818	0.02273								
Z_5 32°	0.00370	0.18750	0.21210	0.21429	0.22222	0.17647	0.05455	0.13636	0.15385	0.04167						
Z_6 31°	0.00185		0.06060	0.19643	0.18519	0.17647	0.20000	0.02273	0.02564	0.04167						
Z_7 30°	0.00185	0.12500	0.06060	0.10714	0.18519	0.05882	0.25459	0.25000	0.17999	0.08333						
Z_8 29°	0.00185	0.06250		0.01786	0.05555	0.20588	0.16369	0.34091	0.15385	0.33333	0.11765					
Z_9 28°				0.05357	0.03705	0.08824	0.18182	0.09091	0.25641	0.29167	0.23539					
Z_{10} 27°			0.03030	0.03571	0.01852	0.08824	0.05455	0.11364	0.15385	0.12500	0.17647	0.44444				
Z_{11} 26°								0.02273	0.05128	0.04107	0.35294	0.22222	0.33333			
Z_{12} 25°							0.01818		0.02564	0.04167	0.11765	0.33330	0.66667			
Z_{13} 24°			0.01786											1.0		1.0
Z_{14} 23°																
Z_{15} 22°																
Z_{16} 21°																

Source: U.S. Dep. of Commerce.

[a] ND represents "No Danger"; all temperatures above 35° are in this category.

deriving the conditional probability values in table 1, irrespective of when they occurred during a particular season.

In table 1 the actual temperatures are the independent variables and the forecasted temperatures are the dependent variables. Thus, the table should be read from top to bottom within a particular column. The blanks within the table indicate that this particular forecast temperature/actual temperature combination never occurred. For example, the (Z_3, θ_2) cell is blank. This means that the actual temperature of 35° was never forecasted incorrectly as 34°.[3]

The probabilities of low nighttime temperatures occurring ($P(\theta_k)$) from the historical records are contained in table 2. Lower temperatures are more probable in March than in May of any given year; thus, these probabilities do depend on the period when they are recorded. To take the seasonal effect into account, it was necessary to divide the frost season into four two-week intervals. This is not to say that individual orchardists do not have other prior information available at the time the frost protection decision is made. The implication is that the historical temperature probabilities provide the minimum level of information available without any nighttime forecasts.

Table 2. Historical Prior Probability ($P(\theta_k)$) of Nighttime Low Temperature Readings in Jackson County

Recorded Temperature	March[a] 14–31	April 1–15	April 16–30	May 1–13
ND	0.46108	0.53750	0.49167	0.75899
35°	0	0.00833	0.02083	0.03227
34°	0.02395	0.04583	0.03333	0.02878
33°	0.04192	0.04583	0.08333	0.06475
32°	0.08982	0.06667	0.06667	0.02878
31°	0.04192	0.03333	0.04583	0.02518
30°	0.04192	0.07500	0.09167	0.02878
29°	0.07186	0.06667	0.06667	0.02518
28°	0.07186	0.05833	0.04167	0.00719
27°	0.05389	0.05000	0.01667	
26°	0.04192	0.00417	0.03333	
25°	0.03593	0.00833	0.00417	
24°	0.01198		0.00417	
23°	0.00599			
22°	0			
21°	0.00599			

Source: U.S. Dep. of Commerce.

[a] The frost season in Jackson County starts when the earliest pear variety exhibits bud swelling, one of the stages of bud development. Based on the nine years of available data, the average date for this appears to be March 14. The season ends in May after no freezing temperatures are recorded. The average ending date is May 13.

Utility Functions

The second type of data needed for the model are individual orchardists' utility or risk preference functions. With the cooperation of the Jackson County Extension Agents, it was determined that there are approximately 11,500 acres of pear orchards and about 100 pear orchardists in Jackson County. Approximately 90%, or 10,350 acres, are protected by some means. The protected acreage was further subdivided into the portion protected by orchard heaters and the portion protected by some other device. This resulted in a final acreage figure of 9,800 acres heated by orchard heaters and controlled by thirty-six commerical orchardists, leaving 550 acres protected by some other method.[4]

Of the thirty-six commercial orchardists, twenty-six were interviewed to obtain information concerning their orchard operation. Utility functions were derived by the now well known Ramsey method for eight of the twenty-six orchardists interviewed (Baquet; Byerlee; Davidson, Suppes, and Siegel; Dillon; Halter and Dean; Lin, Dean, and Moore; Mosteller and Nogee; Officer and Halter; Ramsey). These eight orchardists (22% of the producers) controlled 5,060 acres, 52% of the heater-protected acres of pears in the county.

Polynomial equations were fitted by ordinary least squares to the data points obtained; the fitted utility functions showed five orchardists with cubic equations and three with quadratic equations. Each orchardist exhibited risk aversity to some degree in the relevant income ranges. Risk aversity depends upon the sign of b in a quadratic utility function of the form $U(x) = x + bx^2$ (Dillon, Pratt). For higher order polynomials, risk aversity may change as the level of expected income changes. Orchardists 3, 5, and 7 had values less than 0, indicating risk aversity. For the remaining orchardists, risk aversity depends upon the level of expected income. From $75,000 to about $500,000, orchardist 6 exhibited risk aversity. This is in contrast to the range from $500,000 to $550,000, where he exhibited risk preference. (For details, see Baquet; Conklin, Halter, and Baquet.)

[3] For use in the simulation model, the distributions in tables 1 and 2 were smoothed to include missing data points (Schlaifer).

[4] A commercial orchardist is defined to be an orchardist who derives his primary source of income from his orchard operation. County agents estimated that twenty-five acres of orchards would be needed to fit this classification.

Monetary Payoff Tables

The third basic input for the model is the payoff table. This table represents the returns for all possible combinations of the states of nature and the actions. Three relevant actions for orchardists in Jackson County are: a_1 = light no heaters, a_2 = light one-half of the total heaters available, and a_3 = light all the heaters available. The states of nature are the possible temperatures that may occur. These correspond to the temperature from 21° to 35°, with all temperatures above 35° being combined into one state of nature. The payoff table is a 3 × 16 array, each element of which must have a dollar value associated with it.

Each cell of the array $(A_i, \theta_k))$ is calculated for each night from the equation (a_i, θ_k) = (expected gross return per acre for the remaining crop − the expected value of crop loss − the cost of protection + the expected harvest savings) × (the number of acres under the orchardist's management).

The expected gross returns per acre for the current crop are determined as the expected price times the expected yield. The expected prices and yields used in the model were based on "normal" year prices and yields obtained in the survey of orchardists.

The expected value of the crop loss is the value of the possible crop loss on a particular night if no frost protection is provided. The amount of crop loss on a given night is a function of the bud loss, and the bud loss in turn is a function of the stage of development and the temperature. The critical temperatures for 10% and 90% kill for pear buds in eight development stages are given in table 3. To provide the entire range of percentage kills from 0 to 100%, a linear interpolation between the 10% and 90% was made. The two points were plotted, a straight line was drawn between them, and approximations were derived from this relationship.

The relationship between bud loss and crop loss is critical in the determination of dollar losses from frost damage in pear orchards. Personal discussion with orchardists indicated that a normal crop can be obtained with as much as a 50% bud loss. A linear crop loss/bud loss relationship was assumed for bud losses greater than 50%, i.e., the equation was crop loss = 2 (bud loss) − 100, for bud loss ≥ 50. The dollar value of the crop loss is determined as the percentage crop loss times the expected gross return per acre.

Table 3. Critical Temperatures for Pear Buds by Development Stages

Bud Development Stage[a]	1	2	3	4	5	6	7	8
Average temperature for 10% kill	15	20	24	25	26	27	28	28
Average temperature for 90% kill	0	6	15	19	22	23	24	24

Source: Washington State University.

[a] The eight development stages are: (*a*) scales separating, (*b*) blossom buds exposed, (*c*) tight cluster, (*d*) first white, (*e*) full white, (*f*) first bloom, (*g*) full bloom, and (*h*) post bloom.

The cost of heating varies between orchardists as well as between the types of heating methods used. The survey data indicated that full protection costs vary from $22 per acre per night to $75 per acre per night, based on five hours average use per night. Action 1 (no protection) has a zero protection cost associated with it. Based on interviews with orchardists, it has been established that action 3, full protection, will increase orchard temperatures 5°, while action 2, half protection, will raise temperatures 3°. These two temperature effects were incorporated in the model to modify bud loss percentages.

If an orchardist loses some or all of his crop during the frost season, he does not incur some of the harvest costs that occur later in the growing season. Based on the survey results it was determined that for an 84% crop loss harvesting expenses would not be reduced but that for crop losses greater than 84% harvesting expenses would be less than 100%. If the crop loss was 100%, there would be no harvesting expenses. These two points were used to develop a linear relationship between crop loss and harvest cost reductions. The value of the harvest cost reduction is determined as a percentage of total estimated harvest expenses. These expenses were determined for each orchardist. The input data for determining the payoff table is summarized for each orchardist in table 4.

Survey results indicate that spraying and pruning expenses must be incurred, even though the current year's crop has been frozen out. The trees still need to be protected from insects and diseases to assure production potential in subsequent years. These costs are viewed as affecting future rather than current year production and so were not included in the payoff table.

Table 4. Summary of Input Data for Payoff Table by Orchardist

Orchardist	Bartlett Price[a] ($/T)	Bartlett Yield[b] (T/A)	Winter Price[a] ($/T)	Winter Yield[b] (T/A)	Heating Cost[c] ($/night)	Harvest Costs ($/A)
1	66.00	11.35	102.67	7.76	49.00	93.00
2	112.20	11.35	135.96	9.08	27.50	180.00
3	112.20	10.50	164.01	10.82	70.00	181.68
4	176.00	6.80	242.00	9.08	75.00	181.68
5	193.16	7.14	207.39	7.01	22.00	122.00
6	132.00	3.40	157.67	3.27	51.15	100.00
7	112.20	10.95	135.96	11.52	45.54	181.68
8	132.00	11.36	161.33	10.34	55.00	191.90
Average	112.20	10.50	135.96	10.82	47.81	181.68

[a] Prices received in "normal" years, from survey of orchardists.
[b] Yields attained in "normal" years, from survey of orchardists.
[c] Costs are based on an average of five hours usage per night for full protection.

Results from Model Application for Eight Orchardists in Jackson County, Oregon

The computer program makes all of the necessary calculations given the input data described above according to the sequence given in figure 1. In order to provide some insight into the contribution of various factors to the value of the frost forecasts, a number of different runs were made with the simulation model, utilizing various assumptions. These assumptions were: (*a*) the orchardist maximized his expected utility and had no prior information at the time of the nightly forecast, i.e., $P(\theta)$ was assumed to be uniform, (*b*) the orchardist maximized his expected utility and used the historical prior probability distribution of table 2, (*c*) the orchardist maximized his expected monetary value and used the historical prior probability distribution, and (*d*) the orchardist maximized his expected utility, used the historical prior probability distribution, and had perfect forecast information, i.e., there are only 1's in the diagonal of table 1.

For each assumption and for each orchardist, fifteen runs of the simulation model were made representing fifteen different random seasons (Conklin, Halter, and Baquet). The value of the forecast information from each run was added and then divided by (*a*) the number of acres, (*b*) the number of days in the season, and (*c*) 15, to provide an average seasonal per-day-per-acre value for each orchardist, as is shown in table 5. Each column of table 5 corresponds to one of the four assumptions made, in their respective order. The rows represent the eight orchardists except the last row, which is the average across the eight orchardists.

The value of $5.39 per day per acre (column 2) represents an upper bound on the value of

Table 5. Value of Frost Forecasts per Day per Acre

Operator Number	No Prior Information and Utility Maximization	Historical Prior Information and Utility Maximization	Historical Prior Information and Profit Maximization	Historical Prior Information, Perfect Forecasts, and Utility Maximization
	$			
1	89.09	2.02	3.05	5.07
2	228.17	5.37	4.27	7.32
3	254.10	8.66	5.92	10.72
4	268.68	4.89	6.71	10.82
5	217.43	4.98	3.97	6.65
6	49.42	0.74	1.50	3.26
7	178.30	11.21	5.74	14.24
8	254.94	5.27	6.66	10.51
Average	191.39	5.39	4.73	8.57

the frost forecasts provided by the U.S. Weather Service, assuming the orchardists used the historical prior information and only the frost forecasts issued by the agency.

The value of $8.57 per day per acre (column 4) represents the value of perfect forecasts, assuming the orchardists used the historical prior information. The difference of $3.18 per day per acre ($8.57 – $5.39) represents the maximum amount that could be expended on improving the U.S. Weather Service frost forecasting services and keep the users of the forecasts at the same level of utility as they would be without the forecast information. These are only the benefits of perfect forecasts and do not imply that the U.S. Weather Service could, or should, provide perfect forecasts for that expenditure.

The value of $4.73 (column 3) per day per acre represents the upper bound on the value of frost forecasts, assuming that the orchardists had linear utility functions or that they maximized expected monetary values. The difference of $0.66 ($5.39 – $4.73) represents the contribution of risk aversity to the value of the forecast information.

The value of $191.39 (column 1) per day per acre represents the value of the frost forecasts if one were completely ignorant of the historical prior probability distribution and used the principle of insufficient reason to justify using a uniform prior distribution. The difference of $186.00 per day per acre ($191.39 – $5.39) represents the value of the historical prior probability distribution in making frost protection decisions in this situation. It is apparent that in a sixty-day frost season the accumulated value of the forecasts, if one were paying for them, would soon exceed the value of the crop (see table 4). Clearly, no orchardist would pay such amounts for the forecast information. Equally clear is the fact that no orchardist is that ignorant of the prior historical probability distributions. If he were, he is no longer in the pear production business. The importance of the prior information in determining the value of the forecasts should also be apparent. Thus, the economic value assigned to frost forecasts is conditional upon the prior information that one has at the time the frost information is used. The values given in column 2 of table 5 are our "best" estimates of the value of frost forecasts in Jackson County, Oregon, provided that one knows only the historical prior probabilities on any night of the frost season.

Conclusions

Springtime frosts in Jackson County can have serious effects upon the bud development of pear orchards. In order to reduce the crop loss resulting from spring frosts, most orchardists in Jackson County employ some type of protection measure. This paper has used a simulation model of the Bayesian decision process to derive dollar values for frost forecasts provided by the U.S. Weather Service.

The value of the forecast derived here is specific to the eight orchardists and their environmental conditions, and extrapolation to all orchardists in Jackson County cannot be made without assumptions regarding the risk philosophies and other input data of the unsampled orchardists. While we conclude that the frost forecast service is of considerable value to the eight orchardists sampled, general recommendations as to appropriate frost protection strategies for all orchardists cannot be made and the value of the forecast for the entire county cannot be determined. However, the methodology used and the decision framework illustrated has general application to other problems wherein the economic value of information is to be evaluated under conditions of uncertainty.

The value of the frost forecast was confined to the within-year period of a sixty-day frost season. Further analysis would be necessary to evaluate the effect from annual cultural practices including pruning, thinning, and insect and disease control, which influence future or between-year orchard production. Modification of the payoff matrix would achieve this purpose.

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Crop Yields: Random, Cyclical, or Bunchy?

Clifton B. Luttrell and R. Alton Gilbert

This paper investigates whether changes in weather have random effects on crop yields. The data are yield series of several crops for the United States, individual major producing states, and major producing areas. Statistical tests show little evidence of nonrandomness in these series. There is almost no evidence of cycles or bunchiness prior to 1932, none for national average yields or the weighted average for major producing areas. Since 1932 there is some evidence of autocorrelation; however, this appears to reflect the uneven application rate of high yielding inputs, such as fertilizer and hybrid seed.

Key words: autocorrelation, cycles, bunchiness, nonparametric, nonrandomness, randomness, skewness.

With the decline in the nation's stocks of farm products since 1972 and the possibility of smaller government holdings of such products through price-support operations in future years, greater attention is being focused on the short-run food supply situation. Year-to-year fluctuations of crop production are receiving special consideration since, with low reserves, a few successive years of relatively low yields could cause a sharp reduction in the quantity of food available and sharp increases in food costs.

It is generally agreed that weather is a major factor influencing annual variations in crop yields and production. However, there is great disagreement on the pattern of annual weather variations and its influence on yields. Some analysts contend that weather has a nonrandom impact on yields. One type of nonrandomness postulated is cyclical weather patterns that allegedly generate yield cycles of approximately the same number of years with a series of good weather and high yield years followed by a series of poor weather and low yield years. Others have postulated a tendency for several years of yields above trend to be followed by several years of yields below trend. Such a pattern is called bunchiness, a type of nonrandomness with less regularity than periodic cycles.

An analysis of crop-yield patterns is important for determining national food and agricultural policies. One objective of such policies is to prevent large reductions in food consumption as a result of large reductions in supply of farm products. If there are periodic yield cycles, reductions in consumption could be avoided in years of low yields by accumulating reserves in years of high yields. If crop yields display bunchiness but no regular cyclical pattern, an appropriate policy might be to accumulate large stocks of reserves during years of above trend yields and hold them until yields fall substantially below trend. On the other hand, if yields are essentially random, a smaller quantity of reserves would be sufficient to maintain stable consumption.

This article tests the validity of nonrandom yield theories for several major crops in the United States using average yield data for several states and for the nation. The data were selected to test for periodic movements or bunchiness in yields over large enough areas to affect national crop production. The question of periodic movements or bunchiness in yields at specific locations is not considered in this study.

Weather Cycle Views

Belief in weather cycles dates back to the Old Testament days when Joseph interpreted Pharoah's dream to the effect that seven years of good crops would be followed by seven

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years of poor crops and famine. Weather cycle theories were outlined in a systematic manner by W. Stanley Jevons and his son H. S. Jevons in the 1870s and early 1900s, respectively. They postulated that sunspots behaved in a cyclical manner and in turn transmitted their cyclical influences to weather, crop yields, and the business community (H. Jevons; W. Jevons, pp. 194–205). In the 1920s Henry L. Moore, an American economist, traced the origin of business cycles from periodic movements of celestial bodies to weather and crop yields. He reported cycles of eight years' duration (pp. 101–2).

In recent years less emphasis has been placed on the impact of weather and crop cycles on general business conditions. Nevertheless, belief in such cycles has remained widespread. In 1942 Fulmer reported a tendency for large crops of cotton, apples, and wheat to occur every six years as a result of sunspots (pp. 385–405). Another study presents evidence of regularly recurring cycles in cotton yields and bunchiness in grain sorghum yields from 1916 to 1955 in the High Plains of Texas (Lin, Hildreth, and Tefertiller, p. 596). In an analysis of corn yields in Illinois, Indiana, Iowa, Missouri, and Ohio, Thompson reported cyclical weather patterns that caused below average yields during the decades of the teens, thirties, and fifties of the current century and above average yields in the alternate decades (pp. 454–56).

In contrast to the above proponents of weather and crop yield cycles or bunchiness, other analysts have found the impact of weather on crop yields to be random. Foote and Bean could find no evidence of nonrandomness in U.S. corn yields (p. 30). In a study of cotton, corn, and oat yields in Mississippi, Day found little evidence of bunchiness (pp. 713–19).

Nature of the Data

The data for this study are the U.S. Department of Agriculture series on average yields per acre harvested for various crops in the United States as a whole, yields for various states, and weighted average yields for selected groups of states.[1] The series for the United States begin in 1866. The series for some of the states begin in 1866 and others begin several years later (USDA, all references).

The data are analyzed to determine whether year-to-year changes in weather have random effects on crop yields. Several factors in addition to weather are assumed to have influenced yields, especially since the 1920s. These additional factors include variations in soil fertility due to changes in the location of production areas, improved seed, machinery, weed and disease controls, increased use of chemical fertilizer, and government acreage-control programs that removed the less fertile areas from crop production during the 1950s and 1960s. These nonweather influences are assumed to largely affect yield trends with year-to-year yield patterns dominated by changes in weather. Evidence cited in a following section indicates that in recent decades nonweather influences may have also caused several shifts in yield trends, and therefore the statistical test must be interpreted with allowance for this possibility.

The appropriate data for studying yield bunchiness depends upon the objective of the study. In studies by Day and by Lin, Hildreth, and Tefertiller, the motivating issue appears to be the effects of changes in weather on yields of individual farms. The data used in those studies were derived from agricultural experiment station records. Therefore, those studies investigate the degree of bunchiness in yields at individual locations. In contrast, the objective of this study is to determine whether there is bunchiness or a cyclical pattern in total U.S. production of various crops.

For the purpose of this study it is not sufficient to examine just average U.S. yields of various crops. The crop-yield series have been affected by an important development that it not likely to be repeated—the opening of major new territories in the western states for cultivation since the series began in the 1860s. As more land was brought under cultivation, average yields were affected by the fertility of the new lands relative to the fertility of the land already under cultivation. Major producing states are identified for each crop, and the crop-yield series for a number of these individual states are included to deal with the possible biases due to the additional acreage

[1] The grains selected for analysis—wheat, corn, rye, barley, and oats—are the only major grains produced in this nation for which data are available on yields since 1866. Data on yields by state are available since 1866 for all of these grains except oats. Cotton was selected as a major nongrain crop. Individual states included in the analysis have been major producing states in recent years.

brought into production. Crop yields for major producing areas are calculated from the acreage and production data for the individual states. Such series are less likely to be affected by changes in the land under cultivation than average yields for the United States.

The crop-yield series for each of the major producing states are also analyzed for bunchiness since such analysis can provide information about the potential for bunchiness in total U.S. production. To illustrate such potential, suppose that bunchiness is observed for a crop in each of the major producing states, but no evidence of bunchiness was found for the states combined because when some states have been in phases of low yields other states have been in phases of high yields. If in future years the phases of high and low yields for the major producing states were to coincide, bunchiness for the major producing states combined and possibly for the nation would result. On the other hand, if there is no evidence of bunchiness in individual states, less potential exists for bunchiness in major producing states combined or for the nation.

Empirical Results

The statistical tests are for a type of nonrandomness or "bunchiness" in the yield series that occurs when a deviation from trend in one year tends to be followed by a deviation from trend in the same direction the next year. Under this general definition, periods of exceptionally good and bad crop years would not necessarily follow regular patterns in terms of number of consecutive years that yields are either above or below trend. A cyclical pattern in crop yields at periodic intervals is one type of bunchiness; a tendency for such periodic cycles would be indicated by the following statistical tests.

Tables 1 and 2 present three tests for bunchiness.[2] For purposes of these tests, the series are divided into two time periods, the first from the beginning of each series until 1932 (table 1) and the second from 1933 to 1974 (table 2). The series are divided at 1932 because of a change in trend growth of yields at about that time as shown in figures 1, 2, 3, and 4. A sharp change in trend would tend to bias some of the statistical tests for bunchiness.

Nature of the Empirical Tests

The first test for bunchiness is based upon regression analysis. Natural logs of crop yields are regressed against time to estimate a trend line. The test for bunchiness in this regression analysis is a test for first-order positive autocorrelation using the Durbin-Watson statistic.

The Durbin-Watson statistic is not used in the studies of bunchiness mentioned in the previous section because of the authors' concern about nonnormality of yields, particularly skewness. Statistical inference based upon the Durbin-Watson statistic is valid only if the distribution of observations approximates a normal distribution. A test for skewness is presented in the first columns of tables 1 and 2. (For a discussion of the test for skewness and significance levels of the test statistic, see Snedecor and Cochrane, p. 86 and table A3.) The Durbin-Watson statistic is reported in the fifth columns for only those series that are not significantly skewed at the 5% level.

Nonparametric tests of randomness in crop yields need not be limited by the assumption of normally distributed observations. The test statistics reported in the sixth columns of tables 1 and 2 are those used in the Wallis-Moore runs test for phase lengths, a nonparametric test for randomness (Wallis and Moore). This test statistic is based upon the frequency with which first differences of a series change sign. One type of nonrandomness indicated by this test statistic is a series of first differences that change sign from positive to negative and back to positive more frequently than would be expected for a random series. The other type of nonrandomness would be adjacent first differences that change sign less frequently than expected for a random series. The second type of nonrandomness is called bunchiness in this study.

The Wallis-Moore runs test would not be sensitive to certain types of bunchiness in yields. Suppose a pattern of yields is such that they lie below trend for a few years, with annual deviations from trend being random, and then yields change to lie above trend for a few years, with annual deviations from trend again being random. Increases in yields would not necessarily be followed by further increases or declines by further declines.

[2] Tests based upon cotton yields are not presented for table 1 because of the limited number of observations on these yields in the time period covered by the table. Data on yields of oats in individual states are not available for a sufficient number of years to be included in this analysis.

Table 1. Empirical Results from Beginning of Series to 1932

Crop and Area	Skewness Statistic (1)	Regression Coefficient (2)	*t*-value (3)	d.f. (4)	D.W. (5)	Wallis-Moore Runs Test (6)	Runs Test: Nine-Year Moving Average (7)
Wheat							
United States	0.186	0.002	4.159**	65	2.260	4.316	0.790
States[a]	0.058	−0.004	−2.065*	37	2.308	2.070	2.932
Colorado	−0.340	−0.010	−8.412**	62	1.577*	0.993	1.753
Kansas	0.193	−0.001	−1.001	65	1.970	8.948*[b]	0.002
Nebraska	−0.046	0.006	4.057**	65	1.232*	13.679**	−1.796*
North Dakota	0.195	−0.012	−4.470**	52	1.953	7.087*	0.939
Oklahoma	0.163	−0.001	−0.318	37	2.542	0.731	1.653
South Dakota	−0.040	0.001	0.260	52	2.008	0.199	1.656
Corn							
United States	−0.620*	0.0003	0.435	65		0.195	0.203
States[a]	−0.553*	0.0006	0.993	65		0.833	0.265
Indiana	−0.653*	0.002	2.194*	65		0.708	1.053
Illinois	−0.486*	0.004	3.808**	65		4.139	1.073
Iowa	−1.003*	0.002	1.588	65		0.296	0.020
Minnesota	−0.339	0.001	1.374	65	1.773	1.798	0.850
Nebraska	−0.381	−0.006	−3.141**	65	1.722	0.445	0.910
Rye							
United States	0.067	0.002	3.419**	65	1.431*	5.830	0.002
States[a]	−0.305	0.003	1.409	49	1.677	3.534	0.628
North Dakota	−0.058	0.001	0.444	49	1.930	0.201	0.653
South Dakota	−0.436	0.006	1.904	49	1.396*	1.224	0.963
Barley							
United States	0.020	0.0002	0.359	65	1.900	6.681	2.917
States[a]	−0.615*	−0.006	−4.882**	49		0.635	0.963
California	−0.564*	0.006	5.358**	64		3.546	1.457
Montana	−0.321	−0.016	−8.985**	49	1.641	0.107	1.133
North Dakota	−0.968*	−0.007	−2.198*	49		3.317	1.767
Oats							
United States	0.233	0.002	3.412**	65	2.208	0.387	1.908

Note: * = significant at the 5% level, and ** = significant at the 1% level.
[a] Weighted average of yields in the states listed below. Observations for these series are limited to the fewest observations for any of the individual states listed under each crop.
[b] Does not indicate bunchiness but more phases of length one than would be expected for a random series.

The statistics reported in the seventh column of tables 1 and 2 are used in a nonparametric test of this alternative pattern of bunchiness. A trend in yields is calculated as a nine-year moving average centered on each year for which trend is calculated. In this test a run is a sequence of years during which yields were either below or above trend. The test statistic is based upon the number of runs in a series (Draper and Smith, pp. 95–97). This test would show evidence of bunchiness only if the test statistic is negative, indicating that the actual number of runs is less than the expected number.

Test Results, 1866–1932

The discussion of test results concentrates first on data for the period from the beginning of the series until 1932 (table 1). During this period yields are assumed to have reflected primarily the influences of weather and the natural fertility of the land on which crops were grown.

The test results show evidence of skewness in some of the yield series of corn and barley during this period. The skewness is in the negative direction for both crops, indicating that for those series there were upper limits on crop yields near which observed yields tended to fall, but occasionally there were very low yields.

The Durbin-Watson test provides little evidence of positive autocorrelation in crop yields in the period 1866–1932. There is significant evidence of positive autocorrelation for only the following series: wheat in Colorado and Nebraska and rye in the United States and South Dakota.

The Durbin-Watson statistics for rye yields

Table 2. Empirical Results from 1933 to 1974

Crop and Area	Skewness Statistic (1)	Regression Coefficient (2)	t-value[b] (3)	d.f. (4)	D.W. (5)	Wallis-Moore Runs Test (6)	Runs Test: Nine-Year Moving Average (7)
Wheat							
United States	0.481	0.025	19.538	40	1.099*	3.726	1.624
States[a]	0.381	2.289	44.985	40	0.971*	5.262	−1.154
Colorado	0.141	2.538	32.678	40	0.943*	6.847	−1.203
Kansas	0.661*	2.308	40.334	40		2.269	0.260
Nebraska	0.406	2.455	38.117	40	1.842	0.614	1.567
North Dakota	0.272	2.068	23.995	40	0.939*	3.078	−1.203
Oklahoma	0.415	2.263	29.560	40	1.962	0.927	0.894
South Dakota	0.565	1.862	20.183	40	1.353*	2.902	0.370
Corn							
United States	0.648*	0.377	22.484	40		5.120	1.515
States[a]	0.464	3.302	63.181	40	1.979	6.468	0.545
Indiana	0.441	3.482	79.994	40	2.034	0.829	1.244
Illinois	0.298	3.479	66.115	40	1.870	1.685	1.450
Iowa	0.386	3.496	52.818	40	1.969	2.538	−0.576
Minnesota	0.476	3.309	60.437	40	1.985	4.422	0.405
Nebraska	0.591*	2.299	18.253	40		1.118	0.195
Rye							
United States	0.745*	0.025	13.322	40		1.280	1.005
States[a]	0.561	0.034	10.871	40	2.428	2.941	2.293
North Dakota	0.508	2.006	27.806	40	2.713	0.772	1.594
South Dakota	0.633*	1.959	20.284	40		4.860	2.264
Barley							
United States	0.569	0.022	19.314	40	1.508	6.755	0.192
States[a]	0.358	2.955	96.695	40	1.416*	1.784	−0.206
California	0.270	3.153	121.471	40	1.219*	3.780	0.894
Montana	0.063	2.997	54.974	40	1.310*	6.573	0.754
North Dakota	0.480	2.612	39.227	40	1.532[U]	2.591	1.422
Oats							
United States	0.164	0.020	12.747	40	1.837	4.592	2.695
Cotton							
United States	0.068	5.281	134.040	40	0.860*	6.614	−0.154
States[a]	0.153	5.346	112.776	40	0.966*	5.066	0.532
Arkansas	0.040	5.536	92.744	40	0.908*	0.950	−0.504
Mississippi	0.298	5.473	92.676	40	1.274*	2.902	0.195
Texas	0.248	4.896	80.098	40	1.245*	2.795	0.522

Note: * = significant at the 5% level, ** = significant at the 1% level, and U = uncertain.
[a] Weighted average of states listed below.
[b] Symbols for levels of statistical significance are not given for these t-values, since all are significant at the 1% level.

are significant because of a break in the trend around 1910. The trend was positive from the beginning of each series to around 1910 and negative from around 1910 until the early 1930s.[3] The fit of the trend line is improved by regressing the natural log of rye yields for the nation on time and time squared. With the trend reestimated in this way, the Durbin-Watson statistic is 2.219, thus showing no evidence of positive autocorrelation.[4] Therefore, allowing for a nonlinear trend in the log of rye yields, there is no evidence of bunchiness in those yields for the years 1866–1932.

Of the twenty-six crop-yield series in table 1, three have values for the Wallis-Moore runs test statistic that indicate significant nonrandomness. This test statistic is significant at the 5% level for wheat yields in Kansas, Nebraska, and North Dakota. However, as indi-

[3] Yield data by county support the conclusion of a negative trend in yields from 1909 to 1934. County-yield data are available for the agricultural census years, three of which are 1909, 1919, and 1934. For the sixty-four counties in North and South Dakota combined for which rye yields were recorded in 1909, 1919, and 1934, all but twelve had lower yields in 1919 than in 1909 and lower yields in 1934 than in 1919. Yields in all of those twelve counties were lower in the very dry year of 1934 than in 1909.

[4] The form of this regression equation is as follows (with t-statistics below regression coefficients):

$$\ln Y = 2.3115 + \underset{(6.785)}{0.01277}\, T - \underset{(-5.927)}{0.0002}\, T^2, \quad R^2 = 0.436,$$

with Y defined as rye yields and T as time.

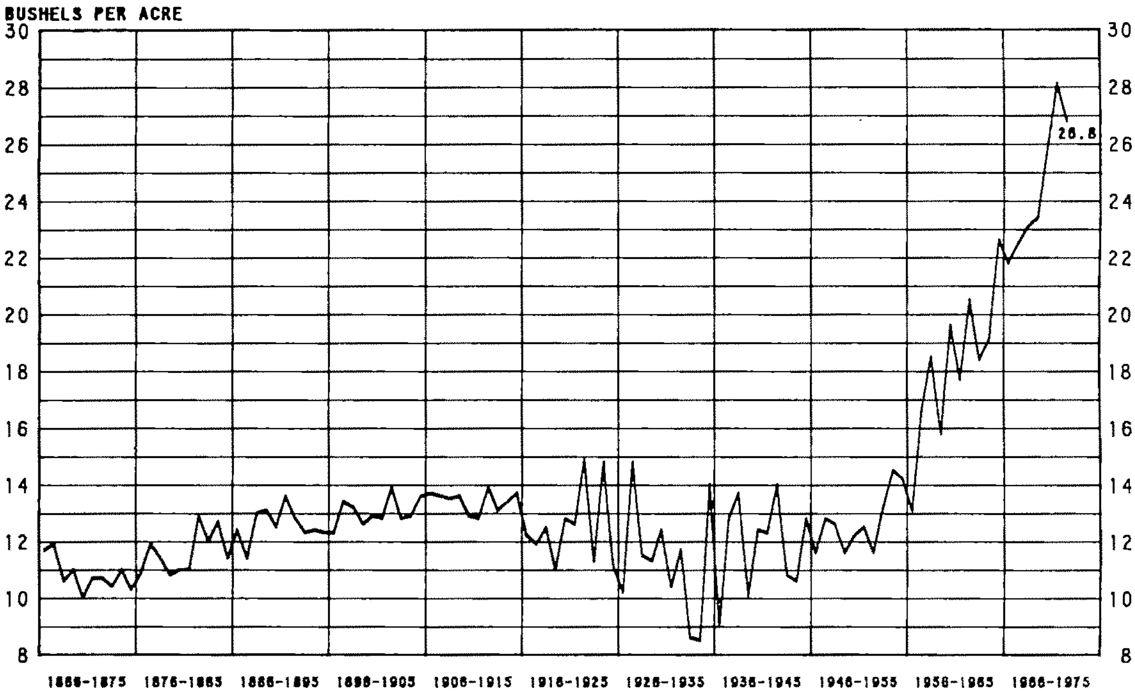

Figure 1. Rye yields per acre harvested in the United States, 1866–1972

cated in table 3, the statistic for wheat yields in Kansas, 1866–1932, is significant only because first differences change signs more frequently than expected, the opposite of bunchiness. This test indicates the greatest degree of bunchiness is in wheat yields in Nebraska. The bunchiness of wheat yields in North Dakota is characterized by changes in yields in the same direction for two years in a row more often than would be expected if the

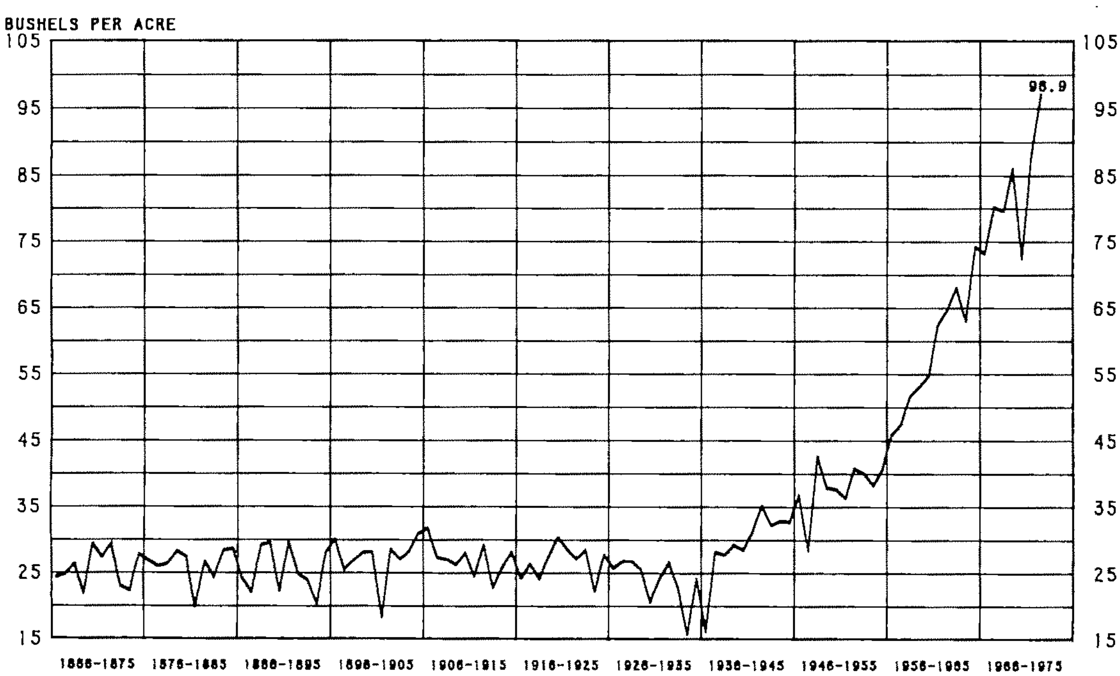

Figure 2. Corn yields per acre harvested in the United States, 1866–1972

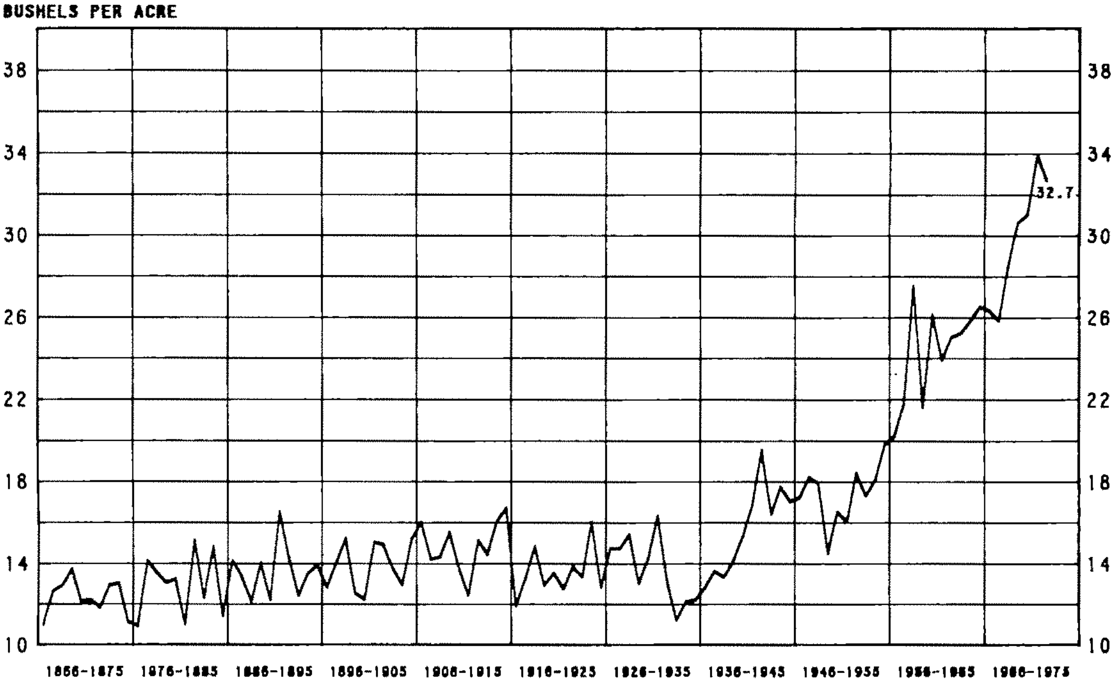

Figure 3. Wheat yields per acre harvested in the United States, 1866–1972

series was actually random. Overall, however, this test on yield data for this period shows little evidence of bunchiness.

Statistics for the runs test with the moving average trend are in the last column of table 1. Since only negative values of this statistic indicate bunchiness, a one-tailed test is conducted. This test of twenty-six crop-yield series shows evidence of bunchiness only for wheat in Nebraska. All of the other series in table 1 have positive values for this statistic, indicating more runs than expected.

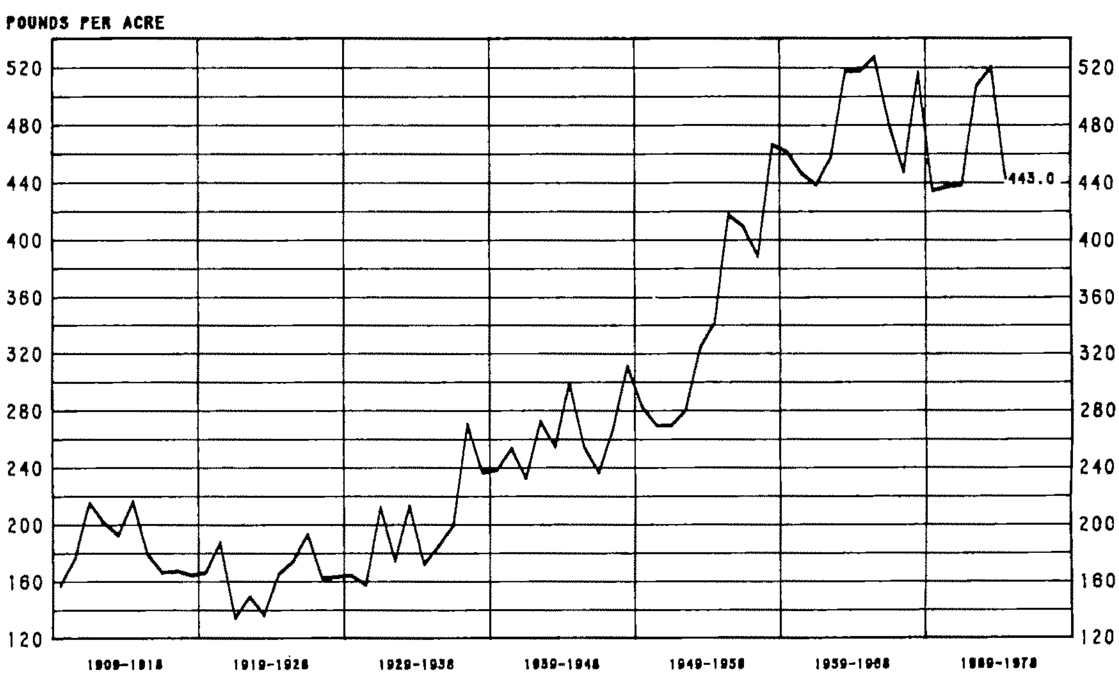

Figure 4. Cotton yields per acre harvested in the United States, 1909–74

Table 3. Analysis of Series with Significant Wallis-Moore Statistics

Crop-Yield Series	Wallis-Moore Statistics	u_1	U_1	u_2	U_2	$u_{>2}$	$U_{>2}$
Kansas wheat, 1866–1932	8.948	39	25.833	11	11.183	1	3.983
Nebraska wheat, 1866–1932	13.680	9	24.583	14	10.633	7	3.783
North Dakota wheat, 1879–1932	7.088	16	19.583	15	8.433	1	2.983

Note: The terms in this table are calculated by counting phases of various lengths in the yield series. A phase is a sequence of first differences of like sign. For instance, if two adjacent first differences have the same sign (either positive or negative), that is counted as a phase of length 2. The following are definitions of terms in this table. u_1 = number of phases of length 1, U_1 = expected number of phases of length 1 in random sample, u_2 = number of phases of length 2, U_2 = expected number of phases of length 2 in random sample, $u_{>2}$ = number of phases of length greater than 2, and $U_{>2}$ = expected number of phases of length greater than 2 in random sample.

In sum, little evidence of bunchiness is found in the crop-yield series for the years 1866–1932. No evidence of bunchiness is found in yields of corn, barley, and oats either at the national or state levels. Some evidence of bunchiness in yields of wheat is found in two states but none is found for average yields nationally or for the weighted average of the major producing states.

Test Results, 1933–1974

The results of tests for bunchiness for this period are presented in table 2. The Wallis-Moore runs test and the runs test with the nine-year moving average trend show no evidence of bunchiness. However, thirteen of the twenty-five series for which Durbin-Watson statistics are presented show evidence of positive autocorrelation, which lends weight to the hypothesis of bunchiness.

Crop yields, which had remained relatively stable since records were begun in the 1860s, have risen dramatically since the early 1930s as shown in figures 1, 2, 3, and 4. Corn yields, which averaged 24 bushels per acre during the decade of the 1930s, rose to 86.5 bushels per acre in the years 1972–74. Average wheat and cotton yields more than doubled, and the index of average overall crop yields has doubled since the 1930s (USDA 1973).

Rising crop yields since the 1930s largely reflect the increasing application to land of man-made productivity factors. Biological science, through more viable seed; chemistry, through lower cost fertilizer; engineering, through more efficient machinery and equipment; and agronomy, through improved crop rotations, soil management, planting, cultivating, and harvesting practices have all contributed to the crop productivity gains.

Identifying the years in which these man-made yield-increasing factors began to have significant impacts on crop yields is somewhat arbitrary. However, since substantial yield increases had begun in the late 1930s and relatively stable yields preceded the 1930s, the breaking point was arbitrarily chosen at the close of 1932.

Uneven Rates in Changes in Yields, 1930s to 1970s

Evidence of positive first-order autocorrelation in yields cited earlier can be interpreted as either indications of bunchiness in yields or increases in the trend of yields at uneven rates over the period from the 1930s to the 1970s. This section surveys evidence of changes in factors that affected yields at uneven rates during that period, supporting the conclusion of shifts in the trend growth rate of yields rather than bunchiness. In other words, evidence in this section indicates that the trend of yields is misspecified by regressing the natural log of yields on time during the period from the 1930s to the 1970s.

Griliches found evidence of the application of new technology to corn production at uneven rates since the early 1930s (1957, pp. 501–5). In another study he found that fertilizer use was inversely related to its real costs, that such costs declined sharply in the early 1940s, and that most of the response to the decline in cost took place within five years (1958). Shaw found that technological changes increased corn yields in Iowa in two steps over the 1929–60 period, the first when hybrid seed corn came into use from about 1935 to 1940 and the second beginning in about 1954 (p. 226). However, results in table 2 show no evidence of bunchiness in corn yields.

On the other hand, average wheat yields have shown some tendency to bunchiness on the basis of the Durbin-Watson statistic. Wheat yields were generally above the trend line from 1940 to 1948 and below it from 1949 to 1956. In part the higher yields in the 1940–48 period may be attributed to more favorable weather conditions during this period, but weather was not the only factor involved. Other factors include the adoption of a number of new varieties of seed, increased summer fallowing, and rising fertilizer use in the Eastern states. A number of new higher yielding hybrids were released for commercial use during this period.

While any evaluation of the factors causing the variation from trend in wheat yields during these periods is difficult, the rapid development of new high yielding varieties and their later susceptibility to disease may have been an important factor. The gains in yields obtained from the adoption of new varieties were often canceled by the development of new strains of rust that attacked the variety. During the 1949–56 period heavy attacks of black stem rust occurred. The attacks were especially severe on the durum and hard spring wheat that are grown extensively in North and South Dakota, two of the three states in which the Durbin-Watson statistics indicate positive autocorrelation. Yields per harvested acre of durum in the nation declined from an average of 15.2 bushels in 1940–48 to 11.3 bushels in 1949–56. By 1956 rust-resistant varieties had been developed and average yields rose.

In addition to the rust problem, changes in the location of production within the states, the beginning of fertilizer usage, and improved machinery that contributed to more timely seeding and harvesting in the 1940s may have contributed to positive autocorrelation in wheat yields.

Positive autocorrelation is also observed in cotton yields since 1933 on the basis of the Durbin-Watson statistic. Numerous factors including better weed and insect controls, increased use of fertilizer, and improved tillage practices contributed to that tendency.

Major changes in production patterns in the cotton belt states as a result of government acreage-control programs in the 1950s and 1960s also had an impact on yields. The acreage removed from production was probably less fertile than those acres remaining in production. During the period 1949–53, prior to the sharp decline in cotton acreage resulting from the government programs, average cotton yields were below trend (figure 4). However, yields were above trend from 1954 to 1966 when acreage declined rapidly. From the average of the first period centered in 1951 to the average of the second period centered in 1960, the acres planted in cotton declined at a 5.7% annual rate and average yields rose at a 5.2% annual rate. In contrast, from 1930–32 to 1970–72 the acres planted in cotton declined at a 2.8% annual rate and yields rose at a 2.4% rate.

Probabilities of Low Crop Yields

An important consideration in formulating a national grain reserve policy is the probability of several consecutive years of bad crops. The evidence presented above indicates no cyclical or bunchy patterns in crop yields (when adjusted for shifts in trends) over large enough areas to affect national production. Therefore, deviations of crop yields from trend are considered to be random, and probabilities of consecutive years of low yields are estimated accordingly. Two definitions of a bad crop year are used in table 4—yields 5% or 10% below trend. The past variability of yields in each series is used to estimate the probabilities of yields 5% and 10% below trend for one year, two years, and three years in a row. To illustrate the use of table 4, the variability of wheat yields in the United States for the years 1937–68 indicates that the probability of wheat yields being 5% or more below trend in any one year is about 22%, for two years in a row, 4.5%, and for three consecutive years, just over 1%.

The numbers below each probability figure in table 4 indicate the frequency with which various percentage deviations from trend occurred. For instance, during the years 1937–68, wheat yields in the United States were 5% or more below trend in seven out of thirty-two years, or in about 22% of those years. These frequencies of actual occurrence of bad crops provide a check on the randomness and symmetry of the crop-yield series. If the frequencies were to diverge greatly from the probabilities calculated using the normal distribution, the yield data would tend to be nonrandom, skewed, or both. The frequencies are fairly close to the probabilities, especially the probabilities of a bad crop in any one year.

Table 4. Probabilities of Yields 5% and 10% below Trend for One, Two, and Three Years in a Row

		5% below Trend[a]				10% below Trend[a]			
Crop and Area[b]	SD[c]	5/SD	Prob.[d]	(Prob.)^2	(Prob.)^3	10/SD	Prob.[d]	(Prob.)^2	(Prob.)^3
U.S. wheat, 1870–1928	10.857	0.460	0.3228 18(59) [0.305]	0.1042 4(59) [0.069][e]	0.0336 0(59)	0.92	0.1788 9(59) [0.153]	0.0320 1(59) [0.017]	0.0057 0(59)
U.S. rye, 1870–1928	8.730	0.57	0.2843 11(59) [0.186]	0.0808 2(59) [0.034]	0.0230 0(59)	1.15	0.1251 4(59) [0.068]	0.0157 1(59) [0.017]	0.0020 0(59)
U.S. oats, 1870–1928	12.886	0.39	0.3483 19(59) [0.322]	0.1213 4(59) [0.069]	0.0423 0(59)	0.78	0.2177 10(59) [0.169]	0.0474 2(59) [0.034]	0.0103 0(59)
U.S. wheat, 1937–68	6.563	0.76	0.2236 7(32) [0.219]	0.0450 1(32) [0.032]	0.0112 0(32)	1.52	0.0643 1(32) [0.031]	0.0041 0(32)	0.0003 0(32)
Wheat states, 1937–70	11.451	0.44	0.3300 14(34) [0.412]	0.1089 7(34) [0.212]	0.0359 3(34) [0.094]	0.87	0.1922 7(34) [0.206]	0.0369 2(34) [0.061]	0.0071 1(34) [0.031]
U.S. oats, 1937–68	7.158	0.70	0.2420 9(32) [0.281]	0.0586 1(32) [0.032]	0.0142 0(32)	1.40	0.0808 2(32) [0.063]	0.0065 0(32)	0.0005 0(32)
U.S. barley, 1937–68	4.781	1.05	0.1469 5(32) [0.156]	0.0216 1(32) [0.032]	0.0032 0(32)	2.09	0.0183 0(32)	0.0003 0(32)	— 0(32)
Barley states, 1937–70	6.075	0.82	0.2061 7(34) [0.206]	0.0425 1(34) [0.030]	0.0088 0(34)	1.65	0.0495 2(34) [0.059]	0.0025 0(34)	0.0001 0(34)
Corn states, 1937–70	7.271	0.69	0.2451 5(34) [0.147]	0.0601 0(34)	0.0147 0(34)	1.38	0.0838 3(34) [0.088]	0.0070 0(34)	0.0006 0(34)
U.S. cotton, 1937–70	7.604	0.66	0.2546 11(34) [0.323]	0.0648 4(34) [0.121]	0.0165 1(34) [0.031]	1.32	0.0934 3(34) [0.088]	0.0087 1(34) [0.030]	0.0008 0(34)
Cotton states, 1937–70	10.082	0.50	0.3085 10(34) [0.294]	0.0952 2(34) [0.061]	0.0294 0(34)	0.99	0.1611 5(34) [0.147]	0.0260 1(34) [0.030]	0.0042 0(34)

[a] Trend is a nine-year moving average centered on each year for which trend is calculated.
[b] Yield series in this analysis are not skewed according to the tests in tables 1 and 2.
[c] The deviations of yields from trend are calculated as percentage deviations from trend. SD is the standard deviation of those percentage deviations from trend.
[d] If percentage deviations of crop yields from trend are distributed approximately as a normal distribution, the probability of crop yields being 5% or more below trend can be estimated by dividing 5 by SD and finding the probability that corresponds to that quotient in a table of the normal distribution. The same sort of analysis applies to the probabilities of yields 10% or more below trend.
[e] This frequency indicates that in the fifty-nine years of 1870 through 1928 national wheat yields were 5% or more below trend for two years in a row on four occasions. This frequency is expressed as a ratio by dividing 4 by 58, since there were only fifty-eight possible combinations of two years in a row.

Conclusion

An analysis of average yields for a number of major crops in the nation and in leading producing states provides little evidence that yields are either cyclical or bunchy as a result of weather. There is almost no evidence of bunchiness in the period 1866–1932 when there was little influence of new inputs on yields. There is some evidence of positive autocorrelation in yields since 1933. However, such results appear to reflect the uneven rate of applications of high yield producing inputs rather than a nonrandom influence of weather. Evidence indicates that utilization of such inputs as fertilizer, hybrid seed, etc., has been bunchy, having been determined by new discoveries, the dissemination of such knowledge, and changes in relative prices.

No attempt was made to analyze yield patterns in areas smaller than states. If periodic yield patterns exist at individual locations or in small areas, they are apparently offset by yield patterns elsewhere or have an insignificant

impact on average yields for major producing areas and the nation.

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National Farm Capital Accounts

Richard W. Simunek

Farm capital flows and finance accounts are quantified to the extent possible using national economic accounting procedures applied to existing farm sector data. Outmoded concepts and data gaps preventing accurate monitoring of economic performance are identified. Current accounting definitions cause substantial capital formation to be recorded as asset valuations. Measures of book value capital consumption allowances, net real estate transfers, and saving in the capital finance account reveal that internal capital financing is important for its magnitude and certainty. The national farm capital accounts improve income and production analysis.

Key words: balance sheet, capital finance, capital flows, economic accounting.

The purpose of this article is to illustrate and discuss the extension of the farm sector accounting system by the addition of change in balance sheet, capital flows, and capital finance accounts. Opening and closing balance sheets are linked by capital flows and asset revaluations. The capital flows account delineates the forms in which capital is accumulated, and the capital finance account monitors its manner of internal and external financing. Methodology employed to construct the national farm capital accounts involves well-recognized national economic accounting concepts (United Nations) quantified to the extent possible with existing farm-sector data. Contrasts between present and proposed accounting rules are drawn and data deficiencies are noted. The national farm capital accounts are presented on the product basis for the farming sector; that is, all nonfarm capital and financial flows and stocks are excluded.

Background

It has been stated that structural and technological changes over time have rendered the theoretical concepts of the farm-sector data system obsolete. As a result, "predictive analysis built upon these concepts performs less well despite great efforts at statistical manipulation of data, refinement of technique, and elaborate economic modeling" (AAEA Committee on Economic Statistics, p. 868). Use of national economic accounting concepts and procedures will help alleviate this situation. This is not to imply that other accounting systems are incorrect or inferior. Each accounting system is designed for a specific purpose. Measurement of the value of production (table 1) is the main purpose of national economic accounting because production of goods and services allows consumption and net capital accumulation (Simunek 1975). In the capital flows and finance accounts, the primary concern is the measurement of net capital accumulation and saving, that is, production not consumed (Simunek 1974).

Development of national economic accounts made possible quantitative economic analysis in the framework illustrated by table 2 and, in turn, increased interest in national economic accounting concepts and the data collection efforts required to support and extend such a system. National economic accounts facilitate economic analysis by identifying the nature of accounting relationships that must hold true; for example, saving must equal net capital formation. Measuring component flows facilitates analysis of functional relationships between, for instance, consumption and disposable income, wages and profits, and capital formation and consumption. Facilitating economic analysis is one facet of national economic accounting; facilitating data

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The views expressed are those of the author and do not necessarily represent those of the U.S. Department of Agriculture. Estimates in this article are not official USDA estimates but are presented to illustrate an accounting procedure. Initial development of the national farm capital accounts began in discussions with Eldon Weeks and Carson Evans, agricultural economists in the Sector Performance Measures Program of the Economic Research Service. Without their insight and guidance, it would not have been possible for this paper to have been written. Lillie Jones assisted with data development. My appreciation is extended to all. Final observations and conclusions and therefore errors are mine.

Table 1. Income and Product Account Using Product Concept

Debit	Credit
Intermediate products consumed	Value of sales[a]
Own-account production	To other farms
Purchases	To other sectors
Interfarm purchases	Own-account uses
Other purchases	Intermediate product consumption
Gross value added	Personal consumption
Capital consumption	Fixed capital formation
Indirect business taxes	Changes in inventories
Net value added	
Employee compensation	
Rental payments	
Interest payments	
Operator's surplus	
Charges against production	Value of production

[a] Would be detailed as own-account uses.

gathering is the other. National economic accounting concepts and procedures force coordination and systemization of basic economic statistics and assist in locating statistical gaps and weaknesses within and between economic accounts and sectors. A useful discipline is provided by the fact that debits must equal credits and sector accounts must sum to the national accounts.

In recent years, attention has been drawn to the limitations of the data system for the food and fiber system as a whole, as opposed to emphasizing those of individual data series or accounts within the system. Issues have been identified and/or suggestions offered requiring expanding the present farm-sector data system or developing an alternative accounting system that represents extensions of existing performance measure series. Weeks (1971, 1972), Weeks et al., Carlin and Smith, and Carlin and Handy examined farm accounts for measuring the value of farm production using the establishment and product concepts of industry. In reference to capital stocks and flows, Weeks observed that nonmeasurement of farm supplies in the inventory account, own-account (nonpurchased) capital formation,

Table 2. Areas of Economic Analysis and Policy in Relation to the National Economic Accounts

National Economic Accounts	Opening Assets	Production	Consumption	Accumulation	Rest-of-the World	Revaluations	Closing Assets
Opening Assets				Studies of national wealth; analysis of productivity			
Production		Input-output analysis; analysis of productivity	Consumers' demand analysis; studies of govt. spending	Models of stockbuilding and fixed capital formation; investment policy	Export demand analysis		
Consumption		Production functions; analysis of productivity; analysis of factor shares	Distribution and redistribution of income; fiscal policy	Depreciation analysis; investment allowances	Studies of the return on foreign investment; double taxation policy		
Accumulation	Studies of net worth		Analysis of saving behaviour	Monetary policy and liquidity preference	International finance and liquidity; long term foreign aid policy	Studies of capital gains and losses; capital gains tax policy	Studies of net worth
Rest of-the-World		Import demand analysis	Short-term foreign aid policy	International finance and liquidity; long-term foreign aid policy	Analysis of balance of trade payments		
Revaluations				Capital revaluations			
Closing Assets				Studies of national wealth; analysis of productivity			

Source: United Nations.

and certain livestock and perennial crop assets distort income and product flows.

Items treated as fixed capital assets in the total net farm income concept (table 3) for which gross capital expenditures and capital consumption allowances are estimated include dwellings, service structures, land improvements, automobiles, motortrucks, tractors, and other machinery and equipment.[1] Estimates of capital consumption allowances are based on current replacement cost, the amount necessary at current prices to replace buildings and equipment used up during the year.[2] Under the present accounting practices, own-account capital formed and used up is not recorded in gross capital expenditures and capital consumption allowances. In addition, orchards, vineyards, animals used for wool and hair, breeding livestock, and dairy cattle are not considered fixed assets under the total net farm income concept. Expenditures for these assets are treated as current expenses. Cash receipts for culled dairy and breeding livestock are recorded as current income. Time and identity imbalances are thus created in the current account.

Valuation of own-account capital stocks is conceptually included in the balance sheet, although production efforts associated with own-account capital formation are excluded from the present measures of capital flows. All assets in the balance sheet, whether purchased or formed on own-account, are valued at their full replacement cost. Market value of own-account assets is reflected in land prices and livestock and crop inventories. Measures of motor vehicle and machinery flows and stocks include only purchased capital under present accounting definitions.

Change in Balance Sheet Account

Legitimate questions can be raised about the present treatment of certain capital items in the farm income accounts, especially as they are eventually measured in the change in balance sheet account. The procedure followed below is to establish the change in balance sheet account (table 4) as the difference between beginning and ending balance sheets and to explain balance sheet changes by capital flows (table 5). Column 3 shows the total balance sheet value change between two accounting dates. Columns 4 through 9 show the amounts of change accruing to balance sheet components as a result of transactions and asset valuations. The change in balance sheet account readily demonstrates that any nonmeasurement of net capital formation in the capital flows account leads to its being recorded as asset valuations in the balance sheet account. This result supports very strongly adding the output of capital formed on own-account to current measures of farm capital formation.

Capital Flows Account

All entries in the capital flows account are economic activities registered in the farm income accounts except net real estate transfers to nonfarm sectors. Thus, by monitoring the capital accumulation process, the capital flows account monitors the direct effects of farm income on the balance sheet. Gross capital formation in the capital flows account consists

[1] Land improvements are not depreciated in the farm expense accounts.

[2] Market value capital consumption allowances will be greater than book value capital consumption allowances during periods of rising prices, especially for longer-lived assets. For example, market value capital consumption allowances for machinery and equipment equal 89% of their gross capital expenditures in 1974, while market value capital consumption allowances for dwellings equal 310% of their gross capital expenditures.

Table 3. Total Net Farm Income of Farm Operators, 1974

Debit	$ Million	Credit	$ Million
Farm production expenses	73,405	Gross farm income	101,112
Current operating expenses	50,892	Value of sales	93,521
Capital consumption allowances	10,640	Government payments	530
Taxes on farm property	2,980	Value of farm products consumed directly in farm households	1,299
Farm mortgage interest	2,986	Gross rental value of farm dwellings	4,880
Net rent to nonoperator landlords	5,907	Other farm income	882
Total net farm income of farm operators	26,072	Net change in farm inventories	−1,635
Charges against output	99,477	Output	99,477

Source: USDA 1975a.

Table 4. Change in Farm Balance Sheet Account, 1974

Item	Balance Sheet of the Farming Sector January 1, 1975 (1)	Balance Sheet of the Farming Sector January 1, 1974 (2)	Total Value Change (1 − 2) (3)	Due to Transactions: Capital Acquired (4)	Capital Consumption (5)	Capital Assets Transferred (6)	Debt Incurred (7)	Total Transactions (4−5−6−7) (8)	Due to Asset Valuations (3−8) (9)
Assets ($ million)									
Real estate	371,355	325,339	46,016	3,536	3,737	1,113		−1,314	47,330
Land	307,111	268,828	38,283	283		920		− 637	38,920
Service structures	30,744	26,772	3,972	2,387	2,223	92		72	3,900
Dwellings	33,500	29,739	3,761	866	1,514	101		− 749	4,510
Nonreal estate	97,781	103,397	− 5,616	6,124	6,903			− 779	− 4,837
Machinery and motor vehicles	50,193	39,485	10,708	7,759	6,903			856	9,852
Livestock and poultry	24,570	42,378	−17,808	450				450	−18,258
Crops	23,018	21,534	1,484	−2,085				−2,085	3,569
Financial assets	15,060	14,877	183	183				183	
Claims ($ million)									
Liabilities	77,538	69,570	7,968				7,968	−7,968	
Real estate debt	46,305	41,253	5,052				5,052	−5,052	
Nonreal estate debt	31,233	28,317	2,916				2,916	−2,916	
Proprietors' equity	406,658	374,043	32,615					−9,878	42,493

Source: Consolidated balance sheets computed from Evans 1975.

of increases in inventory and gross additions to fixed assets.[3] Gross capital disappearance consists of capital consumption allowances and assets transferred out of the farming sector. Inventory change is a component of gross farm income and capital consumption allowances are included in total farm expenses. Asset transfers normally consist of trade-ins and the salvage value of scrapped assets, in addition to capital transfers. However, asset transfers in the farm capital flows account consist of only net real estate transfers, because gross capital expenditures on machinery and motor vehicles are estimated on a net purchase basis (net of trade-in value) in the farm income accounts.

Sales and purchases of real estate within the farming sector represent only a transfer of ownership and not a change in the magnitude of capital available for the production of crops and livestock. It is therefore inappropriate to include purchases of real estate as gross capital expenditures in the capital flows account based on national economic accounting procedures except to the extent that net acquisition of real estate from nonfarm sectors is positive in value. The net decline in acres in farms reported in *Number of Farms and Land in Farms* is valued by the average value per acre sold to nonagricultural uses reported in *Farm Real Estate Market Developments* to estimate net real estate transfers to nonfarm sectors (USDA 1975b, c).[4]

Subtracting all transfers of real estate to nonfarm sectors from all acquisitions of real estate from nonfarm sectors equals net real estate transfers under national economic accounting concepts. An estimate of net real estate transfers under these circumstances can be positive or negative in value, although acres in farming remain constant from one year to the next. For example, assume 1,000 acres in the farm sector valued at $500 per acre

[3] Inventory change derived for total net farm income is consistent with the main purpose of national economic accounting, which is the measurement of current production exclusive of capital gains or losses; that is, no current production "stands behind" capital gains. Net inventory change in the total net farm income concept reflects only physical change as the quantity change in inventory stock is valued at the calendar year average price. An inventory valuation adjustment is made to nonfarm business profit to eliminate inventory profit or loss from the Internal Revenue Service data used to estimate nonfarm income and product. No valuation adjustment is necessary for farm inventories because of the estimation procedures used but, as a matter of interest, the farm crop inventory valuation adjustment for 1974 would equal $3,569 million ($1,484 million minus −$2,085 million) if the IRS data were used and all farmers reported inventory change using the accrual method of accounting (see table 4).

[4] Acres in the farming sector are published annually beginning with 1950. The prices per acre of land sold for nonfarm uses and for all uses are available beginning in 1972 and 1967, respectively. Prior to 1972 the price per acre of land sold for nonfarm uses is estimated.

Table 5. Farm Capital Flows Account, 1974

Debit	$ Million	Credit	$ Million
Gross capital expenditures[a]	11,295	Capital consumption allowances[a]	10,640
Land improvements	283	Dwellings	1,514
Dwellings	866	Service structures	2,223
Service structures	2,387	Machinery and motor vehicles	6,903
Machinery and motor vehicles	7,759	Net real estate transfers[b]	1,113
Inventory change[a]	−1,635	Land	920
Crops	−2,085	Dwellings	101
Livestock and poultry	450	Service structures	92
		Net capital formation[c]	−2,093
Gross capital formation	9,660	Gross capital disappearance plus net capital formation	9,660

[a] Source: USDA 1975a.
[b] Source: Estimated from USDA 1975b, c.
[c] Residual.

are transferred to nonfarm sectors and 1,000 acres in nonfarm sectors valued at $300 per acre are transferred into the farm sector. Net real estate transferred for the farm sector equals $200,000, although the change in acres equals 0. It is probably safe to assume acquisitions of real estate from nonfarm sectors are minimal for recent years and that the estimate of net real estate transfers provides a close approximation of the true value.

Defining Capital Stock

Inputs used up during a period of account are classified as intermediate products consumed, and inputs yielding benefits into the future are classified as capital assets under national economic accounting concepts. Breeding stock, draft animals, dairy cattle, and animals raised for wool are classified as capital assets, as recommended by the United Nations. Livestock considered to be fixed assets by the United Nations enter into capital flows under present concepts but as a change in inventory stocks. Inclusion of the production of these livestock in the capital flows account as fixed capital formation would transfer appropriate current farm production expenses into gross capital expenditures, and livestock depreciation would increase capital consumption allowances. To gain a feel for the magnitudes involved, a recent study revealed that the farm operators' total 1973 net income is lowered 21% by redefining dairy and breeding cattle from current to capital account (Dyer).

Other items not presently accounted for either as assets or inventory stocks that could be classified as capital assets include bearing trees, vines, and other perennial crops. Because perennial crops are land related, expenditures on their establishment, maintenance, and improvement included in current farm expenses are accounted for as real estate valuation gains in the balance sheet. This blurs identification and measurement of cause and effect relationships among production, investment, and saving.

Own-Account Capital Formation

Gross capital expenditures for buildings in the farm income accounts rely on data that include purchases of the entire building plus installation. They also include purchases of building inputs such as nails, lumber, roofing material, and cement. Purchases of the latter type indicate own-account capital formation through proprietors' labor, but due to the method of data collection no estimate of own-account capital formation can be made. Gross capital expenditures on land improvements are analogous to buildings and on machinery and motor vehicles are limited to purchased capital only. The problem of appropriately identifying certain perennial crop and livestock capital assets involves a change in definition. However, the total net farm income accounting format, with its major emphasis on marketplace transactions, offers no solution to the latter problem; that is, capital valuation increases will always be overstated to the extent of own-account capital formation.

The income and product account is illustrated as an accounting alternative for measuring own-account capital formation through the example of a farmer who constructed a dairy barn in 1970 after receiving a private contractor's bid of $85,000 (Machan). Using lumber

sawed from the operator's own woods and purchased secondhand materials, the dairy barn was built for $23,000.[5] The dairy farmer estimated that the cost would have been over $100,000 if a private contractor had built it in 1973. To maintain consistency between the 1970 capital flows account and the balance sheet, gross capital formation on the dairy barn should be valued at its current market value of $85,000 rather than at the $23,000 input cost. Replacement cost capital consumption charges should be calculated on the $85,000 market value of own-account capital, and a capital gain of over $15,000 should be recorded from 1970 to 1973. However, under the present cash concept used in estimating total net farm income, gross capital expenditures equal $23,000, and a capital gain of $77,000 is registered in the balance sheet from 1970 to 1973. A shift from own-account capital formation to purchased capital in this example would cause capital formation to increase $62,000 ($85,000 minus $23,000) as measured under the present accounting concepts, although the real magnitude of capital formation has remained constant. Clearly the imputed market value of own-account capital formation will always be measured either as asset valuation gains in the balance sheet, as is done under present accounting concepts, or as gross capital formation in the capital flows account under a new economic accounting scheme.

Farm Supplies

Inputs to current production are accounted for at the time of purchase under current accounting concepts and not necessarily at the time of actual use as required for production analysis under national economic accounting procedures. Purchases of farm supplies are appropriately recorded in current farm expenses, but changes in stocks of farm supplies are not included in net farm inventory change. This distorts income and product flows, and recent events have placed increasing importance on Weeks' initial observation. The 1974 balance sheet of the farming sector indicates that farmers timed their purchases of intermediate products to reduce their income taxes. The $0.9 billion increase in the farmers' liquid financial assets during 1973 did not match the record $1.2 billion rise during 1972, although farm income increased a record 84%. "The moderate gain in farmers' liquid financial assets during 1973 was somewhat less than might be expected in view of their record high net farm income" (Evans et al. 1974, p. 13). Among the explanations offered for this result was "with the high farm income of 1973, probably a larger number of farmers paid cash for certain items such as fertilizer and fuel before the beginning of 1974 for tax purposes."

[5] This example is not unusual. Popular farm magazines contain numerous examples of own-account capital formation in regular do-it-yourself or homemade features attesting to the importance of this type of economic activity.

Capital Finance Account

Agricultural finance research is too heavily oriented toward microeconomics, and significant gaps exist concerning knowledge of the relationship between national economic policy and capital formation in agriculture, asserts Brake. "Economic theory provides the basis for delineating hypotheses to be tested and specifying the relationships to be measured. In many cases gaps in our knowledge of agricultural finance issues stem directly from gaps in the underlying economic theory" (p. 1056). I agree wholeheartedly and would also suggest that past financial research has been limited by lack of a national accounting framework for farm capital financing. To increase the knowledge of the farm capital financing process, Simunek and Evans estimated a capital finance account based on national economic accounting concepts. The results are reproduced in table 6 and figures 1 and 2.

There are difficulties in monitoring farm capital accumulation and finance with both the flow of funds as computed by the Federal Reserve System and the sources and uses of cash funds statement for the farm sector (Penson, Lins, and Irwin; Smith). Flow-of-funds accounting by the Federal Reserve System includes gross capital expenditures, farm inventory change, and financial asset change as farm capital accumulation. Capital consumption allowances at replacement cost value and total farm debt increase are questionably included as capital finance. This has resulted in the illusion of continual net cash disinvestment in the farming sector since 1955 (Simunek and Evans).

Capital accumulation in the farm capital finance account equals gross capital formation plus net acquisition of financial assets. Inter-

Table 6. Farm Capital Finance Account, 1960–74

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	Total
Capital finance account	Million $															
Gross capital expenditure[a]	4,488	4,614	5,022	5,411	5,688	6,105	6,688	7,446	6,696	6,865	7,285	7,357	8,045	10,535	11,295	103,540
Inventory change[a]	397	336	620	629	−817	1,042	−83	657	124	99	6	1,397	861	3,627	−1,635	7,260
Financial asset change[b]	−446	92	352	59	354	417	323	581	583	408	543	717	873	853	183	5,892
Accumulated capital	4,439	5,042	5,994	6,099	5,225	7,564	6,928	8,684	7,403	7,372	7,834	9,471	9,779	15,015	9,843	116,692
Capital consumption allowances at book value[c]	3,119	3,141	3,235	3,344	3,448	3,582	3,758	4,020	4,286	4,510	4,783	5,243	5,484	6,076	6,838	64,867
Capital consumption allowances at replacement value[a]	4,337	4,388	4,530	4,696	4,903	5,111	5,384	5,781	6,200	6,574	6,760	7,350	7,887	8,937	10,640	93,478
Less: depreciation valuation adjustment[d]	1,218	1,247	1,295	1,352	1,455	1,529	1,626	1,761	1,914	2,064	1,977	2,107	2,403	2,861	3,802	28,611
Net real estate transfers[c]	1,494	1,588	1,562	1,148	1,452	1,830	2,139	2,599	2,429	1,700	1,936	1,559	1,234	1,169	1,113	24,952
Capital borrowing[c]	711	872	1,006	1,166	915	1,398	1,473	1,502	933	1,084	1,092	2,160	2,538	3,111	3,193	23,154
Saving[d]	−885	−559	191	441	−590	754	−442	563	−245	78	23	509	523	4,659	−1,301	3,719
Capital finance	4,439	5,042	5,994	6,099	5,225	7,564	6,928	8,684	7,403	7,372	7,834	9,471	9,779	15,015	9,843	116,692
Cash flows																
Net farm borrowing[e]																
Including CCC Loans	1,404	2,287	2,921	3,000	2,416	3,854	3,371	3,368	3,059	2,572	1,457	4,630	6,231	8,792	7,713	57,075
Excluding CCC Loans	1,179	1,811	2,732	3,129	2,799	3,989	3,622	3,105	1,808	2,567	2,257	4,244	6,700	9,835	8,144	57,921
Internally generated funds[f]	3,728	4,170	4,988	4,933	4,310	6,166	5,455	7,182	6,470	6,288	6,742	7,311	7,241	11,904	6,650	93,538
Farming income of proprietors[g]	13,860	14,545	14,811	14,721	13,566	16,267	17,544	15,868	16,040	18,136	17,896	18,547	24,065	41,654	35,781	293,301

[a] Source: USDA 1975a.
[b] The net increase in currency and time and demand deposits (Evans 1975).
[c] Estimated.
[d] Residual.
[e] The increase in total debt for farm and nonfarm purposes.
[f] Book value capital consumption allowances, net real estate transfers, and saving.
[g] Total net farm income of farm operators based on book value capital consumption allowances plus net rent paid to nonoperator landlords.

nal capital financing consists of capital consumption allowances, net real estate transfers, and saving. Capital borrowing is the net increase in total farm debt to acquire motor vehicles and equipment, construct buildings, and make major repairs and improvements to land and buildings. It is the only source of external financing and is estimated.[6]

Capital consumption allowances equal depreciation plus accidental capital damage. They are the replacement cost capital and consumption allowances as reported in *Farm Income Statistics* converted to book values based on the 1969 book value farm balance sheet and the depreciation rates used for estimating total net farm income (Evans et al. 1971, USDA 1975a). The 1969 balance sheet is the only available national benchmark measuring farm assets at their book value. The difference between the book value and the replacement value capital consumption allowances in table 6—the depreciation valuation adjustment—is a residual. Farm financial analysts currently derive cash flow from income as cash receipts minus cash expenses and, while perhaps adequate for financial purposes, this procedure sidesteps the issue of depreciation valuation and the residual estimate of saving.

National income technicians desire replacement cost capital consumption allowances in the capital flows account for interindustry comparisons and calculating rates of return. In no way do capital consumption allowances inflated for price increases accurately record internal funds available for capital financing. In the first place, the incentive to increase capital formation is affected through reduction in income tax obligations by changes in investment and depreciation tax laws as related to book value depreciation. Second, the relationship between capital formation and capital borrowing is dependent upon book value depreciation. The depreciation valuation adjustment of $28,611 million from 1960 to 1974 in table 6 is 124% of capital borrowing, supporting the observation that external cash flow requirements are influenced by book value capital consumption allow-

[6] A detailed explanation of the procedures and data sources used to estimate capital borrowing is contained in Simunek and Evans.

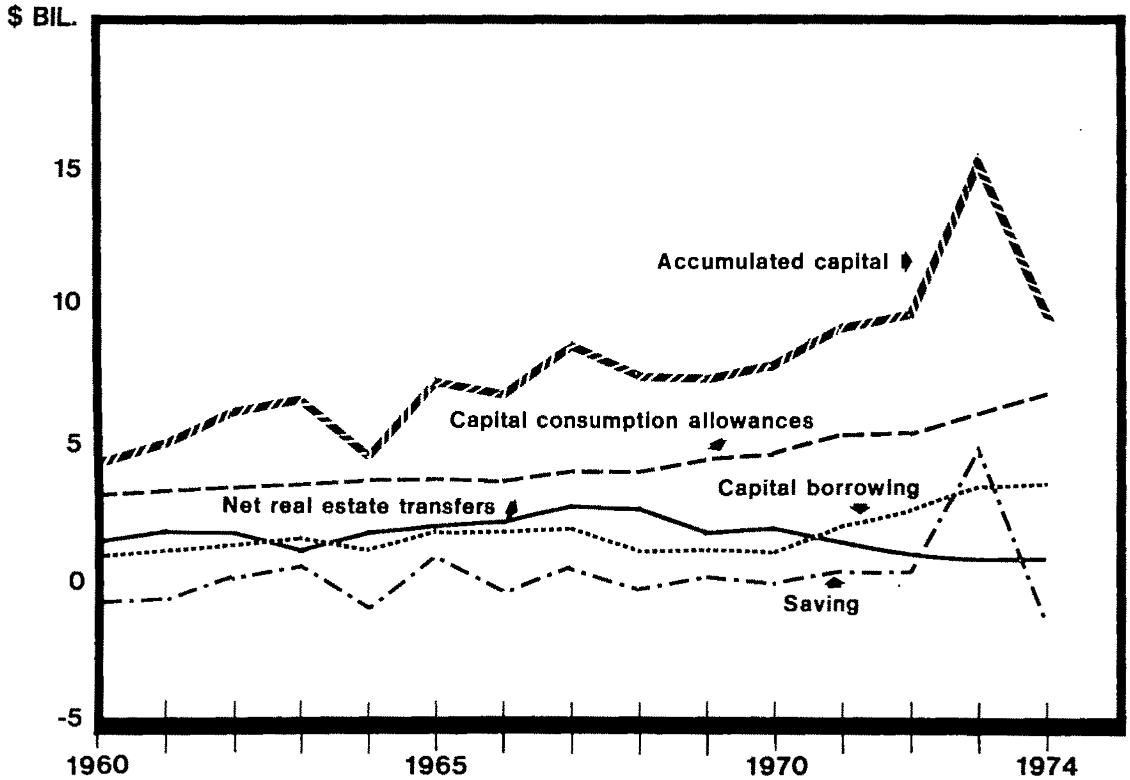

Figure 1. Farm capital finance

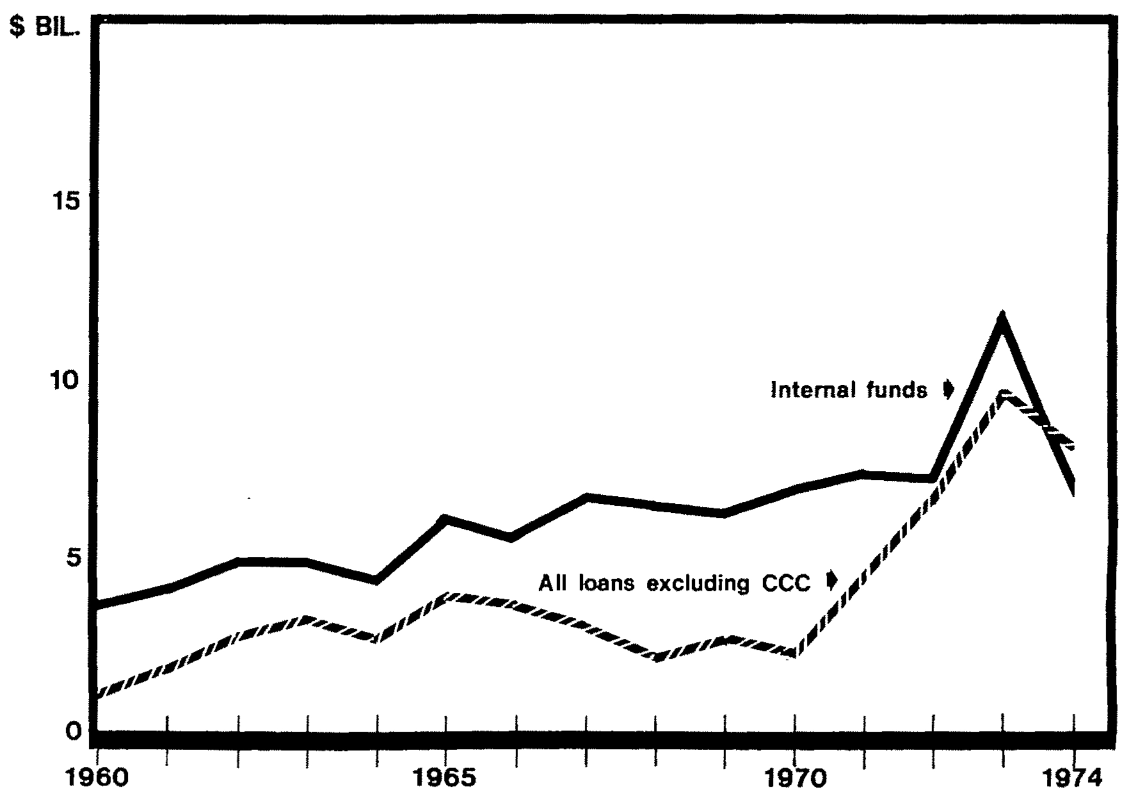

Figure 2. Annual net flow of farm funds

ances. Finally, capital gains or losses are not ignored in the capital finance account but are properly recorded in the assets transferred series as trade-ins, scrapped assets, and assets transferred. For instance, acres of land transferred to nonfarm sectors are valued at their current market value and not at their book value.

Saving is derived as a residual by subtracting capital consumption allowances at book value, net real estate transfers, and capital borrowing from accumulated capital. It is the amount of current production not consumed, while dissaving is the amount of capital stock consumed.

Farm capital accumulation totaled $116.7 billion from 1960 through 1974 or 204% of net farm borrowing for all purposes (including Commodity Credit Corporation [CCC] loans). Internal capital finance explains how farm proprietors were able to carry such a heavy financial burden. Internally generated funds dominate farm capital financing from 1960 through 1974, accounting for 80% of total capital finance, and exceed net farm borrowing for all purposes.

Internal capital financing is important not only because of its magnitude but also because it is a fund source not immediately subject to disruptions in the national money markets. Net farm borrowing excluding CCC loans decreased from $3,622 million in 1966 to $3,105 million in 1967, but internally generated funds increased from $5,455 to $7,182 million, causing a total cash fund increase of $1,210 million. A similar effect occurred from 1969 to 1970, although total funds increased only $144 million. Both periods were times of tight credit (Evans et al. 1971). Apparently, the existence of large amounts of internal funds from book value capital consumption allowances and net real estate transfers plus the potential contribution of saving provides a substantial and assured capital financing base for farm capital acquisition.

Book value capital consumption allowances display a gradual increase in value that is expected since their flow is determined primarily by existing capital stocks on hand, and the influence of annual changes of capital expenditures on depreciation flows is therefore lessened. Net real estate transfers contribute significantly to capital finance and may help to explain the existing paradox of low farm saving versus high farm productivity. Low saving generally indicates low or decreasing productivity for nonfarm sectors. Transfers of farm land to nonfarm sectors represent an exchange of labor-intensive capital for labor-saving capital and at the same time lighten the burden of farm saving.

Farm saving divided by farming income equals a farm saving rate of less than 1.3% from 1960 to 1974. Other factors contributing to low saving are the current definitions of fixed capital assets and gross capital formation. Nonmeasurement of own-account capital formation has a two-fold effect on lowering the estimate of farm saving. First, lack of an estimate of own-account capital formation at the moment of appearance decreases saving by a like amount. Second, that portion of own-account capital not retained in the farming sector is included in asset transfers at full market value.

Farm saving does not equal the total saving required of the economy for farm capital formation. Capital borrowing in the farm capital finance account equals saving by nonfarm sectors and is recorded as saving in nonfarm capital finance accounts. Saving must equal net capital formation for the economy in the national economic accounting framework. For the farming sector, net capital formation in the capital flows account plus financial asset change equals farm saving plus capital borrowing and the depreciation valuation adjustment.

Net real estate transferred in the farm capital finance account is recorded as gross capital formation in nonfarm capital finance accounts. Financial asset change, net real estate transfers, and capital borrowing equal 0 for the nation's capital finance account, assuming no foreign transactions. Saving for the economy can be derived by summing saving in all sector capital finance accounts.

New research areas and priorities are established by the capital finance account. For example, the estimate of saving permits identification of consumption behavior of the farm sector via the consumption function. Because of the importance of internal financing, future farm financial research needs to include investment allowances, depreciation analysis, capital transfers, and saving behavior in conjunction with past farm financial research devoted primarily to interest rates and credit availability. In addition, the role of own-account capital formation as affected by changes in income or capital borrowing needs exploration. Does an increase in income or credit availability cause an increase in total

capital formation or a shift from own-account capital formation to purchased capital?

Summary and Implications

Facilitation of economic analysis and systematization of basic economic statistics are two overall advantages for adopting national economic accounting concepts and procedures for farm sector data and extending such a system to the entire food and fiber system. Economic analysis is facilitated by identifying functional relationships and accounting identities.

Data gaps and weaknesses are readily identified. Adoption of national economic accounting procedures for the farming sector would impose heavy data collection requirements on the U.S. Department of Agriculture for certain items. In other areas, adoption of national economic accounting concepts would not involve any conceptual difficulties other than adjustments to an overall objective. For example, definitions of capital borrowing are not consistent among the Farm Credit Administration, the Federal Reserve System (Melichar), and the Census of Agriculture (U.S. Dep. of Commerce). Also, capital borrowing is not defined consistently with capital formation in the capital flows account.

As stated previously, the national farm capital accounts are quantified to the extent possible with existing farm sector data with the objective of illustrating and discussing accounting concepts and identifying data deficiencies. Empirical results in this article should be viewed and used with discretion. Future efforts will be devoted to improvement of data sources and estimation procedures.

Much capital formation is not presently recorded in the capital flows account but is included in current income and expenses and as asset valuation gains in the balance sheet. A complete accounting of gross farm capital formation cannot be achieved by redefining items considered fixed assets from current account to the capital account. Own-account capital formation will always be recorded as asset valuation gains under the present accounting procedures.

Internal capital finance is important due to its magnitude and its certainty as an available source of funds. Measurement of saving permits identification of farm consumption and saving behavior.

National economic accounting concepts were applied to existing farm data series to develop change in balance sheet, capital flows, and capital finance accounts. In doing so, outmoded concepts and data gaps preventing accurate monitoring of economic performance are identified. Adoption of suggested asset definitional changes and measurement of own-account capital formation will greatly improve the national farm capital accounts for income and production analysis.

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Notes

Some Alternatives to Linear Unbiased Estimation and Traditional Pretest Procedures

George Judge

In economics the most widely used statistical technique is based on the linear statistical model and least squares and maximum likelihood concepts. These tools are supported by a body of theory that dates back well over a century to Gauss and Legendre and includes the powerful and beautiful Gauss-Markoff theorem, which says in effect that, out of the class of linear unbiased estimators, least squares is the "best" (minimum variance, minimum mean square error) estimator. The linear unbiased restrictions that are necessary to achieve the Gauss-Markoff result appear to be generally accepted in econometric analysis. However, for the economic researcher who is interested in parameter estimation or prediction appropriate for choice or decision purposes, the property of unbiasedness, which yields an estimator that is right on the average, may have limited usefulness. In addition the best unbiased statistical property only holds if the statistical model is correctly specified, and in economics the sampling process by which the data are generated is seldom known.

Consequently, the purpose of this expository note is to point out that over a range of criteria for evaluating estimators, distributional assumptions, and conditions normally fulfilled in practice, simple estimators exist that are uniformly and nontrivially superior over the parameter space to the least squares and pretest estimators used by most applied researchers in economics.

A Comparison of Traditional and Nontraditional Estimators

As a basis for presenting and contrasting the estimators, let us for expository purposes assume the data are generated by the orthonormal linear statistical model

(1) $$y = X\beta + e,$$

where y = a $T \times 1$ vector of sample observations, X = a $T \times K$ design matrix with $X'X = I_K$,[1] β = a $K \times 1$ vector of unknown parameters, and e = a $T \times 1$ normally and identically distributed vector of random variables with mean 0 and covariance matrix $\sigma^2 I_T$. The traditional least squares, maximum likelihood estimator of β for the orthonormal statistical model is

(2) $$b = (X'X)^{-1}X'y = X'y,$$

where b among linear unbiased estimators has for all β a minimum variance, either component by component or for any linear combination.

The first hint of difficulty for those using this estimator came in 1956 when Stein showed that under a squared error loss measure,[2] $\rho(b, \beta) = E_\beta[(b - \beta)'(b - \beta)]/\sigma^2 = K$, the least squares estimator was inadmissible, i.e., there exists another estimator, say, $\hat{\beta}$, where $\rho(\hat{\beta}, \beta) \leq \rho(b, \beta) = K$ for all β and $\rho(\hat{\beta}, \beta) < \rho(b, \beta) = K$ for some β. In other words, under the standard measure of performance there is a "better" estimator.

In 1960 James and Stein exhibited an estimator that under squared error loss and number of parameters $K \geq 3$ had a risk equal to or less than the least squares estimator for each point in the parameter space. The simple estimator they proposed and showed to have smaller total squared error loss for all β is

(3) $$\delta(b) = (1 - ((K-2)/(T-K+2))((T-K)\hat{\sigma}^2/b'b))b,$$

where b is defined in equation (2) and $\hat{\sigma}^2$ = the unbiased least squares estimator of σ^2. All elements of equation (3) are contained in the output of the usual regression computer program. If we have hypotheses concerning the K unknown parameters, say, β_o, then the estimator may be written in the more general form

(4) $$\begin{aligned}\delta_o(b) &= [1 - ((K-2)/T-K+2)((T-K)\hat{\sigma}^2/(b-\beta_o)(b-\beta_o))](b-\beta_o) + \beta_o \\ &= [1 - ((T-K)(K-2)/K(T-K+2))/F](b-\beta_o) + \beta_o \\ &= [1 - c^*/F](b-\beta_o) + \beta_o.\end{aligned}$$

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[1] This assumption is made for expository convenience. If the general case, where $X'X$ is a positive-definite matrix, is assumed as Bock, Yancey, and Judge have shown, the conclusions remain and only the conditions change.

[2] Since for a random sample of observations $(y_1, y_2, \ldots, y_t)$ there may be several estimators to choose from, there is a need to introduce a loss function $L(\hat{\beta}, \beta)$ that will reflect the loss or disutility incurred by choosing a particular estimate when β is the true parameter vector. Since the observations y are random, the loss function will also be random. We can then define the risk function $\rho(\hat{\beta}, \beta)$ as the expected value of the loss function. An ideal choice of estimator is one that minimizes the risk for every possible value of the β vector parameter space. However, minimum expected loss estimators for all elements of the parameter space rarely if ever exist except in trivial problems.

The following equation is distributed as an F-random variable with K and $T - K$ degrees of freedom and noncentrality parameter $(\beta - \beta_o)'(\beta - \beta_o)/2\sigma^2$:

$$(5) \qquad F = (b - \beta_o)'(b - \beta_o)/K\hat{\sigma}^2 .$$

When $\beta = 0$ or $(\beta - \beta_o) = 0$, the risk of the James and Stein estimator is $[K - ((T - K)/(T - K + 2))(K - 2)]$ and increases to K, the maximum likelihood risk, as $\beta'\beta$ or hypothesis error $(\beta - \beta_o)'(\beta - \beta_o)$ approaches infinity. At the origin the gain from using the Stein rule, equation (3), may be substantial, depending on T and K, and the gain is positive over a large part of the parameter space.

The moral of the Stein-rule result is that if choice is restricted to linear unbiased estimators the relative risk losses that accrue may be great. By using the Stein rule one can never do worse than the least squares rule, and there is a considerable range of the parameter space where one wins. Thus, simple rules, which result in nonlinear and biased estimators, can improve the sampling performance of the estimators when three or more parameters are involved. It has often been asked in a decision context why so much stress is placed on unbiased sampling theory estimators, which are correct on the average. Results from such rules as the Stein rule make the question all the more embarrassingly difficult to answer.

Traditional and Nontraditional Pretest Estimators

When there is uncertainty about the statistical model and thus restrictions or hypotheses to impose, a traditional way to proceed is by statistical hypothesis testing based on the data at hand, followed by estimation. The econometric literature abounds with exact and approximate tests for identifying sins of omission and comission relative to a variety of false linear models. Thus, for example, use is made of the test statistic F given in equation (5) to test the hypothesis $H_o: \beta = \beta_o$ against $H_a: \beta \neq \beta_o$. H_o is rejected if $F = (b - \beta_o)'(b - \beta_o)/K\hat{\sigma}^2$, which is distributed as a central F-distribution with K and $T - K$ degrees of freedom, is greater than some critical value c determined by the level of the test α. Another example is the stochastic assumption of zero-order autocorrelation where the Durbin-Watson test for autocorrelation is made. On the basis of this test, one goes with the original model or estimates the autocorrelation coefficient and transforms the statistical model. While this two-stage estimation rule is used in much applied work, the econometric literature is strangely silent as to the statistical consequences of making use of the formal and informal pretest or sequential estimation procedures. As recent work by Bock, Yancey, and Judge and others has shown, under criteria commonly accepted for defining "good" estimators, the traditional pretest estimator performs badly (larger squared error loss relative to the least squares estimator) over a large part of the parameter space.

However, worse is to follow—not only does the pretest estimator perform badly relative to the least squares estimator but it turns out that Sclove, Morris, and Radhakrishnan have exhibited an estimator that is uniformly superior to the pretest estimator over the whole range of the parameter space; that is, there exists another estimator that has a squared error loss that is equal to or less than the pretest estimator for all α and for all comparable α levels of significance and corresponding critical values c of the F-test statistic. Furthermore, for some critical values c, the Sclove, Morris, and Radhakrishnan estimator is uniformly superior to both the pretest and least squares estimators over the whole range of the parameter space.

The Sclove, Morris, and Radhakrishnan estimator is from the family of Stein-rule estimators and in fact results when the James and Stein estimator equation (4) is modified in the following way:

$$(6) \quad \delta_{01}(b) = I_{[c,\infty)}(F)(1 - c^*/F)(b - \beta_o) + \beta_o,$$

where $c^* = (T - K)(K - 2)K^{-1}(T - K + 2)^{-1}$ and $I_{(\cdot)}(F)$ = an indicator function that is 1 if F falls in the interval $(\cdot)$ and 0 otherwise. This means the original Stein-rule estimator equation (4) is modified by the rule that $\delta_{01}(b) = \beta_o$ if $F < c$. The Sclove modified Stein-rule estimator equation (6) demonstrates the inadmissibility of the traditional pretest estimators. Monte-Carlo sampling experiments by Yancey and Judge suggest that the losses from using the pretest estimator instead of the modified Stein rule are over a large part of the parameter space nontrivial in nature.

Concluding Remarks

In general, in both econometric theory and practice, sampling theory estimators for the linear statistical model are restricted to the linear unbiased class. For the researcher, however, who is interested in parameter estimation or prediction appropriate for choice or decision purposes, the statistical property of unbiasedness that yields an estimator that is right on the average may have limited usefulness. On the other hand, if one is willing to lay down the cross of unbiasedness and consider nonlinear biased estimators under squared error loss, the family of Stein-rule estimators introduced in the late 1950s dominate (i.e., uniformly superior over the parameter space) the least squares and maximum likelihood estimators under conditions normally found in practice. As Efron and Morris have noted, the Stein-rule estimators can be recommended on the basis of simplicity, generalizability, efficiency, and robustness (over distributional assumptions and performance

criteria). In spite of these qualities, there is little or no mention of these estimators in the econometric literature and applications of the Stein-rule procedures in economics have only started to be explored. Perhaps the time is ripe for applying one of the family of Stein-rule estimators as we work with our false linear statistical models.

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Guided Analysis: An Experiment in Educational Technique

Timothy M. Hammonds

Everyone who takes a serious interest in undergraduate teaching is capable of reciting a list of comparatively recent innovations in educational technique. The terms individualized instruction, computer-assisted study, self-learning center, and self-contained learning module (to name a few) have been added to most of our vocabularies, if not to our actual teaching repertoire. Yet no single innovation has emerged as clearly superior to the others or to the conventional lecture format.

After attending numerous seminars on these techniques, the author has drawn two conclusions. First, variety is essential. This means that no single innovation is likely to sweep all others aside. Second, by concentrating on the method of delivery, it is possible to break material into units so small that students lose the power to integrate its concepts.

A new educational technique known as guided analysis is now evolving, which is consistent with both of the observations just cited. It promotes variety of delivery in the educational program, and it places heavy emphasis on concept integration. If one accepts Maslow's hierarchy of needs, then the highest level of intellectual activity is to become an independent decision maker.[1] This suggests that much of the advantage to be gained through higher education is in the ability to face a new problem area, to bring acquired knowledge to bear on unfamiliar ground, and to reach a workable decision by evaluating a variety of alternative solutions. This process is something more than the sum of individual building blocks of knowledge.

One of the major difficulties facing educators is that the transition from skill acquisition to problem solving in an unstructured environment is not a simple one. In an on-the-job environment, problems are often so ill defined that merely recognizing the real nature of the problem takes considerable skill. Guided analysis is designed specifically to bridge the gap between skill acquisition and unstructured decision making.

The objective of this paper is to describe the technique itself and to discuss its application in an experimental program at Oregon State University.[2]

Guided Analysis

The technique was developed at West Virginia University by Wales and Stager for an undergraduate engineering curriculum. Their name for the technique was "guided design," since engineering design situations were the focus. The term "guided analysis" is a corruption by this author in adapting the technique to economic analysis.

The technique itself is most appropriately thought of as a process that serves as a bridge between programmed learning (with some modifications) and the case study method. Case study techniques are useful in higher education. However, the philosophy of guided analysis is that successful performance in open-ended case study situations is a useful goal in undergraduate education but not a useful starting point. The stated goal of this technique is to enable the student to function effectively in the analysis of open-ended case studies that attempt to duplicate on-the-job situations. Instead of thrusting the student directly into this setting with little or no preparation, the process gradually "weans" students from structured problem analysis at a controlled rate. This is a direct rejection of the concept that students develop an adequate decision-making framework from the information delivered in their individual course without additional guidance.

Initially, the technique carefully leads students through an integration of preselected concepts and provides a detailed modeling of the decision-making process expected of a professional in their field. Subsequent problems maintain the emphasis on coursework integration, but the degree of specific guidance diminishes until a case study problem in its traditional sense can be handled. The initial problems of guided analysis make use of the programmed-learning concept with two modifications: the type of problem dealt with and the size of the mental leap between each question in the programmed sequence. In traditional programmed learning, the focus is specific skill acquisition, and a series of very specific problem assignments is utilized. In guided analysis, a series of questions and feedbacks gradually exposes a complex problem setting that the student must eventually grasp as a whole. In traditional programmed learning, the

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[1] Maslow's seventh need is self-actualization: the need to be an independent, adaptive, creative decision maker.

[2] The educational and psychological literature leading to the development of guided analysis will not be reviewed here. Interested readers are referred to Wales and Stager, Feb. 1972 and March 1972, and Bailie and Wales, 1975.

size of the mental leap required from question to question is small and remains small throughout the program. In guided analysis, the mental leap between questions begins small but gradually enlarges as each problem progresses. Toward the end of these initial problems, the student is required to make the mental leap of pulling together his individual pieces of information and analytic results to attack the problem as a whole.

A prime objective of guided analysis is to increase student tolerance of ambiguity. Ambiguity is an inherent component of most professional problem situations. Students not previously exposed to unstructured open-ended problems exhibit a tendency to view the attendant ambiguity as threatening (Budner). Guided analysis gradually moves the student from specific problem assignments to increasingly ambiguous settings as a method of easing the transition to a professional career.

In summary, guided analysis is a process for taking students from specific to open-ended problem settings at a controlled pace. A series of problems is used with the initial problems structured as modified programmed learning and the final problems structured as case studies. The initial problems provide specific guidance with the amount of guidance decreasing with each successive problem. During this process, stress is placed on integration of previous coursework, development of a professional decision-making framework, and increasing tolerance for ambiguity.

During the winter and spring quarters of 1975, this author conducted an experiment in guided analysis at Oregon State University. The winter quarter experiment consisted of a special project utilizing only guided analysis as a technique. The spring quarter experiment integrated guided analysis into the managerial economics class that was a regular part of the curriculum drawing agricultural economics seniors and first-year graduate students as the primary audience. Prior to the winter quarter of 1975, the project was outlined to the sophomore class and volunteers were solicited for a three-credit-hour class. Ground rules included a requirement of prior completion of a mathematics sequence covering calculus and linear programming. Acceptable courses were mentioned by number but with no mention of the specific skills that would be required. Three acceptable volunteers were enrolled and told that they would function as a problem-solving team. Word of the project spread, and an acceptable three-man team from the junior class also volunteered. They were told that class meetings would not be scheduled but that the teams were free to hold group meetings among themselves and to schedule instructor conferences either individually or by teams whenever they felt the need. They were also told that the problem would require periodic reports, some oral and some written.

The spring quarter project consisted of the same problem exercise as part of a managerial economics course taught entirely on a self-learning center basis. Each individual carried out the spring quarter exercise independently; no teams were used.

No further instructions were given prior to the project except for a general information sheet listing the following objectives: at the end of this course you should have (*a*) improved your ability to look at reasonably complex situations, similar to these you might actually face on the job, and to identify the fundamental problem that must be dealt with, (*b*) improved your ability to integrate material from your various undergraduate courses in practical problem settings, and (*c*) improved your ability to communicate your problem solutions in a form acceptable to business management.

The first portion of the project consisted of a seventeen-page handout entitled "An Introduction to the Process of Decision Making." The handout proceeds in programmed-learning fashion to introduce the steps necessary to reach a decision in any problem setting. It therefore provides a skeleton for problem identification, analysis, and action implementation that may be used throughout the course. The handout takes less than an hour to complete and requires no written response. It was originally developed by Wales and Stager (1974) for their engineering program and was used with their permission.

The project itself, the first problem of a guided analysis sequence, consisted of twelve written instructions and twelve written feedbacks. The technique of guided analysis is to present a series of handouts each giving problem information, followed by an instruction requiring the preparation of either a written or an oral report for the instructor. The instructions and feedbacks used in the experiment were developed by this author.

The philosophy of guided analysis is to place students in a setting that they might actually face as a professional in their chosen career. This strategy breeds personal involvement and provides an incentive for completing the assignment. An effort is made to create a specific need for learning or using a technique before the technique itself is introduced. The first handout appears below.

Conrad Assembly Company

Allan White is a junior in the Department of Agricultural Economics at Oregon State University. He is working for the Conrad Assembly Company during the summer and has been assigned to its comptroller, Mr. Stuart.

Mr. Stuart explains that at a monthly planning session of company executives in June, various members of the executive committee expressed dissatisfaction with the company's profit performance as reported in the six-month income statement just prepared. Conrad manufactures and sells combines.

Instruction CAC-1

Allan has lunch with Mr. Stuart his first day on the job. During lunch, Stuart suggests that an appropriate

summer project would be to look at company operations and suggests ways for improving profitability. What type of response should Allan make if he is interested in pursuing the project?

Each team member must write down the suggestions which Allan might make at this luncheon. Turn the suggestions in and obtain the first feedback.

Each response is greeted with a feedback in written form. The feedbacks present an acceptable solution to the previous instruction, additional problem information, and a new instruction. This provides the student with guidance as soon as he turns in his assignment. It has the advantage of instant feedback, as in programmed learning, while the material is still fresh in the student's mind. It has the disadvantage of requiring the instructor to anticipate the response. This can be handled in several ways. First, many of the simple instructions have obvious responses that may be anticipated without difficulty. Second, the intent of many instructions will be merely to channel the students' thinking, and therefore the feedback need not anticipate the response perfectly. Third, oral conferences may be scheduled before the feedback is given. These conferences provide the instructor with an opportunity to deal with an unanticipated response and to prepare the student for the written feedback that will follow.

The ability to provide proper anticipation without being overly heavy handed in instructional directions to students is an acquired skill. This author familiarized himself with the available literature and then attended a two-day workshop given by Wales and Stager. During the workshop, actual course materials under preparation were reviewed and criticized by Wales and Stager. After this initial exposure, the course materials were completed during the fall and pretested on the winter quarter students. A prime objective of the pretest was to detect unanticipated lines of inquiry and to insert additional or modified feedbacks to deal with those approaches. A guided analysis project probably would not prove successful without adequate pretesting.

Of course, it is impossible to anticipate every response. Guided analysis is designed to stimulate independence and creativity. There are two procedures that may be used to smooth any problems caused by a line of student reasoning not covered in the prepared feedbacks. Since the instructor monitors each response as it is turned in, there is opportunity to schedule a special conference to explore differences of opinion. The first alternative is to reconcile an unanticipated direction of response and to move the student back into the prepared sequence. If the student has initiated a line of inquiry that an instructor feels is worth pursuing, a second alternative is to allow the students to receive an oral series of feedbacks for that portion of their work.

The technique used for the first Conrad Assembly Company feedback was merely to channel student thinking into the decision-making process. The actual feedback is presented below.

Feedback CAC-1

If Allan forgot the proper way to begin the solution of an open-ended problem, he and Mr. Stuart might have discussed broad basic solutions. For example, they might have suggested: (1) expanding the sales force to generate more volume, (2) changing the pricing strategy for the company, (3) diversifying into new product lines, (4) closing down unprofitable operations.

Instruction CAC-2

Fortunately, Allan remembers that the proper first step is to define the problem and to state the basic objective. If you were in his position, what objectives would you have specified for his summer project?

Each group member must write down his objective and turn it in before the next feedback is obtained.

As the problem unfolds, the information provided with each feedback becomes more complex, and the analysis required becomes more difficult. This particular problem requires the students to recognize the difference between full cost accounting and contribution to overhead, to discover the need for linear programming in their analysis and utilize this technique in its graphic form, to discover the nature of opportunity cost associated with capacity for constraints, and to employ simple differentiation for input mix selection. Both teams during winter and all fifteen members of the spring class finished the project within a normal ten-week quarter, proceeding at their own pace.[3]

Evaluation

Student feedback on this project was uniformly enthusiastic. All students rated the course very good to excellent on organization, very good to excellent on learning emphasis, and good to excellent on overall rating of the course.[4] Written comments stressed appreciation of a course that emphasized independent thinking versus memorization and integration of coursework versus narrow focus.

However, one should not accept the evaluations from a single course as an adequate indicator of the worth of a new technique. Newness itself can easily bias student attitudes and therefore test results. A more comprehensive set of data collected at West Virginia University is available for a more meaningful analysis.

The concept of guided analysis (guided design)

[3] The nature of all twelve instructions and feedbacks is too complex to report here. The entire project covers twenty-six pages and is available from the author.

[4] A six-point rating scale was used with choices of very poor, poor, fair, good, very good, and excellent. Class size was not large enough to warrant dividing the students into an experimental group and a control group with a comparison of the resultant test scores.

was first applied on a broad scale in 1971 when the chemical engineering department at West Virginia University used it to develop an introductory freshman course, a two-credit course each semester for sophomores, a six-credit course each semester for juniors, and a ten-credit course block each semester for seniors. The first class to progress through this system graduated in May of 1974. The grade point averages of the last two classes who were exposed to guided analysis and of two previous classes who were not are presented in table 1. Four other engineering departments not on this program are included for comparison.

The only classes with a significant positive deviation (5% level of significance) from the college average G.P.A. (grade-point average) were the 1974 and 1975 chemical engineering classes exposed to guided analysis. The difference between 1972–73 and 1974–75 was not accounted for by better entering students. Bailie and Wales (1975) report no appreciable change in entering the students' high school G.P.A., Math A.C.T. (American College Test) scores, or composite A.C.T. scores.

An earlier effort measured the impact of guided analysis (guided design) on selected student personality variables. The results are reported in Tseng and Wales. Their test compared differences between pretest and posttest scores for a group of students in a guided analysis course and a group in a traditional lecture-laboratory program (three semester hours each). Results indicated a significant improvement for the guided analysis group over the control group in increased tolerance for ambiguity and increased internal orientation with regard to locus of control.

Tolerance for ambiguity was discussed earlier in this paper. Locus of control is an expectancy variable indicating whether an individual generally feels that the events of his life are under his own personal control or beyond his own influence (see Rotter for a more complete discussion). An external orientation suggests individuals with an expectation that events are unrelated to their own behaviors. An internal orientation suggests individuals with an expectation that events are under their own control. By encouraging an internal orientation, guided analysis develops a personality trait generally felt to be desirable for a professional (Tseng and Wales).

Table 1. Deviations from the Average College G.P.A. for Selected Departments, West Virginia University, 1972–75

	Graduation Year			
Department	1972	1973	1974	1975
Chemical engineering	−0.02	0.10	0.19	0.19
1	0.02	−0.03	0.04	0.12
2	0.09	−0.02	−0.05	0.04
3	0.03	0.07	−0.08	−0.09
4	−0.14	−0.05	−0.10	−0.35
Average college G.P.A.	2.90	2.86	2.94	2.86

Source: Reproduced with permission from Bailie and Wales, p. 399.

Now for some personal observations on the technique. First, this approach overcomes a weakness in the case study method. In case study analysis, it is easy to focus primarily on the appropriate solutions to each problem. In guided design, a great deal of attention is focused on the method of arriving at those solutions. Students are provided with an opportunity to walk through the method of problem attack expected of a professional in their field.

Second, students are required to recognize the need for a technique previously learned and to use that technique in an applied problem setting. It is one thing to learn linear programming and then to be presented immediately with an exercise demanding its use. It is quite another thing to approach a problem having no advance knowledge of the techniques needed and to recognize the contribution possible from a linear programming approach. Reenforcement of techniques previously learned is essential. A lesson that should be coming through to educators everywhere is that the rate of decay for knowledge not frequently used is astonishingly rapid. Guided analysis provides the instructor with an opportunity to demonstrate the practical importance of various techniques by letting students discover these techniques outside of the normal classroom setting.

Third, students are required to integrate material from several previous courses, mathematics, accounting, and economics, for this particular problem. Based on comments from the winter and spring quarter students, the opportunity for coursework integration should begin early, probably during the sophomore year. Students easily lose sight of the overall direction of curriculum because their view is focused intensely on one piece at a time. The lament "when do we get a chance to put all this together?" has been heard, no doubt, by every advisor at one time or another.

If the reader agrees that one of the fundamental objectives of higher education is to create independent decision makers, then guided analysis holds great promise. The technique helps to prepare the student for a professional work environment and to develop enthusiasm and perspective for the individual skill techniques learned in the many undergraduate courses. It therefore may be used to provide a strengthened sense of direction in the instructional program.

The available evidence is strong enough to suggest that agricultural economists take time to familiarize themselves with the literature on this technique and to consider its use in their own programs.

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An Integrated Approach to Farm Management Education

Kenneth M. Menz and John W. Longworth

Farm management lies well to the vocational end of the theoretical-vocational spectrum of tertiary courses in agricultural economics. Students and potential employers generally expect courses in farm management to contain some exposure to realistic management situations. However, as French has emphasized, it is "relevance" rather than exposure to the real world per se that is required. Furthermore, the application of farm management procedures and methods of pseudo real world situations may achieve relevance at the cost of education. If farm management instruction is to improve the "allocative ability" (Huffman, p. 96) of the students who participate in these courses, then the emphasis must be on concepts rather than on the mechanical use of tools (Boehlje, Eidman, and Walker, p. 196).

The aim of this paper is to describe an approach to teaching farm management that emphasizes self-discovery and relevance. Our technique takes maximum advantage of the motivation and involvement created by a complex, computerized management simulation known as the Central Tablelands Farm Management Game (CTFMG).[1] Our purpose is to show by example how a computer simulation exercise can be integrated with other traditional and nontraditional teaching techniques in an effort to achieve specific educational goals. "Effective teaching requires a flexible instructor who employs multiple teaching techniques which then create an environment where learning takes place both inside and outside the classroom" (Kendrick, p. 766).

By basing the course on a realistic management simulation, we aim to create a classroom environment in which the student learns to recognize management problems and then actually "reaches out for" analytical procedures to help meet the challenges posed by these problems. We view all components of the course as tools for assisting decision making, and we try to introduce each new tool at the time when it will have a maximum impact upon the student. Such timing is based upon consideration of student need (for the management tool) and upon the student's level of prior knowledge. Each tool is evaluated by students in an instructor-led group discussion after the initial usage and then periodically throughout the course in the light of new knowledge that may alter opinions. "Teaching and learning are frequently confused in higher education. . . . One can observe in any classroom that teaching can proceed in the absence of learning" (Kropp, p. 757). Our approach aims to place the emphasis on learning. This is facilitated by relatively small classes (less than thirty-five) and a generous course weighting in the curriculum. The only prerequisite for entry is a one semester microeconomics course. The percentage of students who will ultimately assume a managerial role is not known, but it is unlikely to exceed 20%. On the other hand, a very high percentage of recent graduates are employed in extension-research positions.

The Simulation Exercise in Action

The use of farm management games for instructional purposes is not new. Longworth (1970) presents a history of the gaming concept. The large number of games now available and their diversity presents a real challenge for an instructor who is considering adoption of this teaching technology. However, insufficient attention has been paid to exploring alternative ways in which games can be used for specific purposes (e.g., for learning how to use and critically evaluate farm management decision procedures). We outline below how the CTFMG represents the focus of our course in farm management. Perhaps our experience will encourage others to renew the search for a game suitable for their own purposes and to realize the enormous potential of such games.

Instruction in Planning Methods

Very early in the course each student is presented with a copy of the participants' manual for the CTFMG (Longworth 1973b). This booklet contains a complete description of their farm, the phys-

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The authors are grateful to Mike Hayward and Jim Gaffney for their contributions to farm management education at the University of Queensland.

[1] A slightly out-of-date description of the game including flowcharts and ALGOL 60 computer programs may be found in Longworth (1969a). The programs have since been revised and rewritten in FORTRAN IV. Operating manuals are available (Longworth 1973a, b). The CTFMG is the most widely used computerized farm management game in Australia (Lindner). Tanner reports a detailed survey of student reactions to playing this (and other) games.

ical and economic environment, the resource restraints, and the institutional limitations. It also indicates how the manager is to record his decisions. The enterprises from which each manager must choose include various types of pastures, oats, wheat, potatoes, and livestock (beef cattle, wool, and meat sheep).

Apart from the need to create long-term development and survival strategies, detailed decisions of the following type are required: (*a*) which pasture species to grow, what seeding and fertilizer rates to use; (*b*) what cultural and cropping operations are required and when; (*c*) when to buy and sell livestock and fodder; (*d*) when to perform the various livestock operations such as shearing and mating; (*e*) what machinery and buildings are to be purchased and when; (*f*) what fencing and clearing is justified; (*g*) whether long-term investment in additional land is warranted and, if so, when; (*h*) whether to borrow or use internal financing; and (*i*) which labor source to use—permanent or casual, farm labor or contractors.

As the participant manager has the opportunity to reassess the situation on a monthly basis, he must balance short-term contingency measures against longer-run strategic plans. Initially students can be overawed by being asked to "manage" a farm. However, a careful mix of instruction and consultation can guide them through this critical period.

At the time the participant manager takes over his farm, no activities are in progress. He must, therefore, formulate a whole-farm plan and begin to implement this plan. The formulation of the plan (in detail for the first year and in outline for three years at least) is a major task. The approach that we encourage is to begin with a lecture and subsequent calculation of simple activity budgets leading to the derivation of a matrix of gross margins. Once these calculations have been carried out for all feasible enterprises, the student managers select a combination of activities as a starting plan for their farm, using simplified manual programming. They are then encouraged to modify their initial plan based upon the results of partial and parametric budgets and to assess whether the modifications yield a "better" result. The partial budget is constantly used once simulated management begins, and it is important that students quickly learn to use this simple tool with speed, skill, and confidence. From the outset each manager is required to establish his own economic goals. Thus, the assessment of whether one plan is "better" than another is an individual and personal judgment each student manager must make.

At this stage, students begin to appreciate the need to clarify such concepts as variable and overhead (fixed) costs and the value of understanding the various measures of profit. In fact, this early stage (before the computer simulation begins) is an important segment of the course, since it also provides the student the opportunity to become familiar with the farm to be managed. Students unaccustomed to actively participating in the teaching-learning process take time to "warm up," and we have found it essential to be enthusiastically patient while students get adjusted to the challenges of the course.

Once each student manager is reasonably satisfied with his whole-farm plan, simulated management commences. All decisions are made and results received on a monthly basis, and this keeps the class "on its toes" for the first year of simulated activity. Students soon recognize deficiencies in their expectations and hence in their overall farm plans. By now they realize the relatively arbitrary nature of their original plan and begin to look for a more rational and objective approach. As their original approach involved simple programming using a matrix of gross margins and activity details, it is only a small conceptual step to construct a full linear programming (LP) matrix. Despite a lack of formal instruction most students can construct a simple LP matrix for their farm in less than three hours. To save time, we do not try to solve each student's matrix. Instead a fairly sophisticated LP matrix and solution for a "representative" farm, almost identical to their farms in resource endowments, is made available to each student manager. Having constructed their own simple matrix they have a good conceptual idea of what the more complicated (realistic) matrix means. Furthermore, the solution is also of great interest. They want to know how it was obtained. They perceive the enormous potential value of the information presented in the form of shadow prices, etc. They quickly recognize the great saving in calculating time once the matrix has been set up. On the other hand, upon trying to implement the LP solution, these classroom managers observe the problems of using "average" year coefficients, of neglecting overhead costs, and many of the other well-known limitations inherent in single-period LP models.

In this atmosphere it is easy to extend the programming concept to more advanced models. For example, a multiperiod LP model for the CTFMG is used to demonstrate how fairly simple modifications can be made to the static LP matrix to investigate the optimal firm growth path. Work is currently underway to develop a Monte-Carlo matrix for the CTFMG and, in time, a full range of programming models will be available.

Segments of the simulation model are extracted for exercises designed to illustrate the production function concept. Potatoes are a profitable crop in the CTFMG, and interest in the management of the potato enterprise is high. A fertilizer production function supposedly based on results obtained on an experiment station near their farm is made available to the students, and they are asked (and shown how) to determine the "optimal" levels at which to apply nitrogen and phosphorus to potatoes on their

farm. Not only is a practical application of production theory portrayed, but since students must act upon the basis of the results of their analysis, the following real world considerations are emphasized: (*a*) the precision and relevance of experimentally determined production functions; (*b*) the complications that weather and price risks introduce into production function analysis; and (*c*) the sensitivity of enterprise profits to suboptimal fertilizer rates. It is difficult, if not impossible, to convey adequately these ideas with a static practical assignment of the traditional variety. Students are shown how to incorporate the results of the production-function analysis into the LP model.

Instruction in Record Keeping and Control Procedures

Our experiences with the CTFMG strongly support the view of Boehlje, Eidman, and Walker (p. 195), who state that the "possibilities to add realism to undergraduate farm management education programs . . . appear unlimited." Although the monthly reports prepared by the computer contain all essential records, a number of supplementary records are desirable—e.g., graphing rainfall and the prices of livestock and fodder, recording and monitoring the use of labor, machinery, and livestock feed, and recording fertilizer treatments and stocking rates. The student quickly learns to appreciate the need for a systematic approach to handling the feedback from the dynamic system that he is managing (manipulating). Students frequently develop and design their own visual aids for this purpose.

Students are also given the opportunity to compare actual and budgeted financial results on a monthly (or quarterly) basis. Each student manager is encouraged to utilize the services of a commercial computerized accounting service that is available to farmers (Bureau of Sugar Experiment Stations, Sturgess and Hampson). This accounting service uses the Australia-wide standardized ACCRA code (Australian Committee for Coding Rural Accounts, Gay). At the beginning of the planning year, budgeted expenditures and receipts (coded by the students) are forwarded to the accounting service bureau. When simulated management begins, actual receipts and expenditures are similarly coded and processed by the accounting bureau. In return the student managers receive monthly (or quarterly) comparisons of actual and budgeted cash flows. This allows students to carefully monitor discrepancies between expectations and actual results. Such discrepancies often call for a change in plans, and students are required to test alternatives using partial budgets. As well as emphasizing the control function, this procedure saves a tremendous amount of arithmetic and familiarizes students with the benefits and mechanics of a computerized accounting service.

In any one run of the game, all farms are subject to the same stochastically simulated weather and marketing environment. The independent decisions of each manager are combined with these environmental factors to determine the outcome for his particular farm. The results for each farm are presented to the participant-manager not only as monthly physical and financial summaries but also in the form of a full set of annual managerial accounts. Samples of the output are contained in Longworth (1973b). After each year of management, students are asked to analyze these annual financial accounts. A diagnostic approach is emphasized based upon the comparative analysis of various measures of efficiency with other simulated farms (Burns). This is facilitated by the fact that all farms are subject to the same environment. Again students are required to translate leads obtained from the comparative analysis into improved plans by means of budgeting procedures.

Instruction in Decision Making

Management can be thought of as the art of making decisions with incomplete information. In an earlier article one of the present authors has discussed the use of management games for providing students with practice in this "art" (Longworth 1969b). In that article farm management is portrayed as a cyclical process, and it is hypothesized that management games enable both the "academic" and the "practical" halves of the management cycle to be demonstrated in the classroom. Our experience with the CTFMG strongly supports this hypothesis.

While all aspects of the course relate to decision making, the practical application of decision-theory techniques is given considerable attention. Students formulate a decision problem of interest to them based upon parameters from the simulation model. Past experience has shown that the use of "canned exercises" is of little value in teaching decision-theory concepts. The specification of a real problem within the decision-theory framework and the acceptance or rejection of the solution based upon various criteria are essential to a thorough understanding. In addition to providing a means by which students can experience all aspects of decision making in a managerial context, the CTFMG helps the student develop a balanced judgment regarding the desirability of formal decision analysis.

In another exercise dealing with risk, each student personally uses a recently developed computer management aid to evaluate the riskiness of various sheep enterprises within the CTFMG (Mill and Longworth). An additional benefit of this exercise is to provide some "hands on" experience in the use of computer terminals and library programs as decision-making aids.

Instruction in the Local (Australian) Institutional Framework

Income tax payments and other institutionally determined outlays frequently represent large unavoidable outlays of cash for Australian farmers. These payments must be made annually in the CTFMG. One important feature of the CTFMG is that the full set of managerial accounts prepared by the model for each farm at the end of each year are set out in the Australia-wide recommended format (Joint Committee on the Standardization of Farm Accounting). This adds realism to the game and leads directly to some understanding of accounting principles. To prepare an annual income tax return, the student must first convert these managerial accounts to tax accounts. This exercise emphasizes the fundamentally different concepts embodied in these two different approaches to farm accounting and highlights the way in which income tax considerations may have an important bearing on management decisions.

The simulation exercise also provides a useful reference point for class discussion of many other institutional issues such as estate planning, workers compensation laws, laws of contract, etc. One institutional-sociological issue we endeavor to raise is the relationship between the farmer and his advisors, e.g., extension agent, accountant, banker, private consultant. Many students gain new insight into this relationship when they act as clients of the commercial accounting bureau.

The Development of a Healthy Respect for Biological Information

Many of our students do not have a rural background nor have they undertaken any serious study of the soil-plant-livestock systems that are the bases of agriculture. The CTFMG provides an ideal framework in which these people can learn to appreciate the need for farm economists to have some basic understanding of these systems. The lack of knowledge (or even awareness) of the complexities and uncertainties that farm managers face is brought home to them in this classroom exercise. Inexperienced students, therefore, have the opportunity to develop an appreciation of the management problems faced by farmers. It is critical to their later success in actual management or in extension-research positions that graduates feel a sense of empathy towards the real world farm manager and his problems.

Our primary concern is that each student appreciate the whole-farm (systems) approach to farm management. They quickly learn to acknowledge that the farm is a closely interconnected system where any decision can have widespread ramifications. Economics is seen as the integrating force that holds the farming system together.

Field Trip

The CTFMG as used at the University of Queensland replaces formal lectures to a considerable degree. Students are given references and texts as they need them (as problems arise) and the occasional brief lecture-explanation during formal class contact periods. However, a large proportion of the students' time is spent in active, self-motivated learning.

In addition to the management simulation and associated exercises and lectures, all students undertake a case study of an actual farm. Students visit these farms in small groups, each group accompanied by an advisor. The purpose of the field trip is to compare and contrast management in reality with management of the simulated farm in the CTFMG. In particular, students are asked to consider and to report upon: (*a*) the influence of goals and attitudes of the manager in determining strategies, including considerations of household-business interrelationships; (*b*) problems of data collection in the real world; (*c*) the physical implementation segment of the management cycle; and (*d*) the additional constraints within which the real world manager must operate (social, technological, institutional, etc.).

An Assessment

The basic question of validation is a difficult one indeed. Tanner has reported a survey of students' attitudes towards various methods of teaching farm management. She is "of the opinion that farm management games do have a place in farm management teaching" (p. 60) although "the results of the student survey are not sufficient to establish clearly the superiority of any one of the methods" (p. 62). The course at the University of Queensland has evolved considerably since the time of Tanner's survey. We prefer to assess the additional costs of our current approach over and above the costs of running a course along traditional lines. If, as indicated below, the additional costs are small, then one does not have to demonstrate dramatic benefits to justify our approach. What then are the costs of using the CTFMG?

The time consumed in reflective decision making normally prevents a student from completing more than two or three years of simulated management if every student is assigned his own farm. If small groups of students (less than or equal to three) collectively manage each simulated farm, it is possible to complete at least five years of activity. Under this arrangement students can gain a better appreciation of the longer term consequences of their decisions. However, every student in each group needs to be completely responsible for at least one whole year of management decisions. Using the University of Queensland PDP-10 com-

puter, it takes thirty-three seconds of computer time to process the decisions for one month for ten farms. On this basis, thirty students operating ten farms for five years would use a maximum of thirty-three minutes PDP-10 computing time. However, the actual amount of computer time required will be less than this since the decisions for more than one month are processed together in the later years of the simulation. This modification significantly reduces the processing time required.

The other significant additional cost associated with the game is the labor required to check and input the decisions. Again on the basis of simulating ten farms, about one and a half man-hours per month of decisions is required. Over the fourteen-week semester we use, therefore, about ninety man-hours of labor more than would be the case with the conventional course. While a further charge for the game manual and other materials used in the simulation could be added, it is doubtful that these relatively inexpensive items are really additional costs. In the absence of the game, alternative exercises and associated materials would have been necessary anyway.

Given the physical measure of required computer and labor time above, the interested reader can calculate the additional costs associated with the kind of exercise described in this paper in his own teaching environment. At the University of Queensland the additional cost per student has been calculated to be $20 (Australian currency).

Conclusions

Recent contributions to this *Journal* have emphasized the need for an improved use of available teaching aids, materials, and methods for subjects such as farm management (Boehlje, Eidman, and Walker; French; Plaxico et al.; Sjo, Orazem, and Biere). In this paper we have described an approach based on a complex, computerized farm management game. Although we do not wish to push the analogy too far, our technique could be compared with the approach to M.B.A. training described by Cohen et al. Our conclusions are subjective and impressionistic, but they are overwhelmingly favorable. The integration of a carefully designed farm management game into a course in farm management greatly enhances the relevance of the course. Students learn to use and critically evaluate various tools of farm management and develop through experience an awareness of the problems that practical managers face. Many professions require such an awareness, and the course is considered to be beneficial for these people as well as for practicing managers.

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In Quest of Learning-Teaching Excellence: A Viewpoint

John Sjo

Quality of teaching is so intangible that it is often difficult to recognize, measure, and reward. Outstanding instruction for one student may be miserable instruction for another. Techniques that motivate and excite one student may leave another unmoved. Both the student and the teacher sense and know when learning-teaching situations have been effective. But they are hard pressed to identify how those situations differ from ineffective situations. The changing student-teacher and faculty-administrator relationships and attitudes have affected the learning-teaching environment in universities. In this note, I discuss learning-teaching objectives and the present learning-teaching environment's impact on learning-teaching in agricultural economics.

Objectives of the Learning-Teaching Experience

Learning is very personal, occurring within the individual student but nurtured and brought forth by the teacher. Learning is gaining facts, understanding causal relationships among facts, using that understanding to solve problems and to develop sound judgment, and finally to create ideas that add to knowledge. Although learning can occur only within the individual, the teacher can increase the efficiency of the learning process. Efficiency depends upon the student's ability, motivation, and previous experiences as well as on the learning environment provided by the teacher. The teacher can provide an appropriate learning environment by encouraging, challenging, and exciting the student, by identifying material to be learned, and by providing sources of information. The learning-teaching environment is mutually created by the teacher and the student. Each student-teacher combination requires its unique conditions.

The identification and exposition of the learning-teaching process as best suited to undergraduate instruction in agricultural economics is needed if we are to have more effective learning-teaching situations. Some of our most dedicated and effective undergraduate teachers need to study philosophy of knowledge, theory of learning, and theory of communication and then apply those studies to develop knowledge transfer processes for learning-teaching agricultural economics. The subject matter, in our case agricultural economics, is fairly well mastered by most agricultural economists. Differences in the quality of teaching come less from differences in subject matter knowledge than from differences in the effectiveness of our interpersonal relationships with students.

Even without much knowledge of the learning process some agricultural economists have been great teachers. Great teachers have identifiable common characteristics. In addition to being a master of the subject they teach, they cause those who hear them to want to share that mastery. They accept students as worthy and significant individuals, are sensitive to their feelings and needs, and hear their views and ideas as meaningful. They awaken students to their full potential and urge them to develop it. They light the spark of creativity in students. But above all great teachers are honest in word and deed each time they touch a student's life.

Deterrents to Learning-Teaching

Effective teaching results primarily from the creativity and craftsmanship of the individual teacher. Factors such as quality of instructional facilities, equipment, institutional arrangements, and employment conditions are not the difference between outstanding and poor teaching. Excellence in the foregoing conditions does not assure outstanding teaching, and lack of facilities will not cause poor teaching. The great teacher rises above the conditions to fulfill his creativity and craftsmanship potential.

Yet, environmental factors can increase the incentive for a teacher of any level of competence to fulfill his or her potential. Today, certain factors are deterrents to effective teaching. Because each teacher perceives his environment differently and has had a different set of experiences, the deterrent factors will affect each teacher differently. In my judgment those affecting learning-teaching most are student evaluations of teachers, increasing size of classes, third party liability, formulated budgeting,

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entrance and placement testing, and changing attitudes of teachers and students.

Student evaluations of teachers provide students with the opportunity to inform teachers about student reactions to their classes. Until recently, student evaluations were limited to use by the faculty member as a basis for improving instruction. Now, student evaluations are becoming a part of the administrative evaluation of faculty and affects tenure, promotion, and pay. There are several disincentives to quality teaching when student evaluations are used as a part of administrative decisions. Student evaluations, when given anonymously, may violate the teacher's rights because he is unable to confront and answer his critics. If the students identify themselves on the evaluation, they then must accept responsibility for the evaluation and may be subject to a liability suit.

Most student evaluation instruments emphasize how well the student liked the teacher rather than what the student learned. That criterion may mean that teachers will shift from effective teaching methods to popular ones that assure they are better liked. Being liked and being effective in teaching may not be the same thing. Galbraith has expressed concern that student participation in administrative decisions leads to a lowering of standards. If he is correct, current grade inflation may partially result from student evaluation of faculty.

Student evaluations of instruction are effective instruments for improving instruction but must be used cautiously for pay, promotion, and tenure purposes. Most students lack the experience to make judgments on overall faculty performances. More importantly, because they are at the university for so short a time, they are not accountable for those judgments.

Total expenditures for higher education have been increasing rapidly because of increasing enrollment, inflation, and new programs. To meet citizen concern about higher total expenditures, university governing bodies and administrators have sought ways to increase productivity. The usual way has been to increase the average size of classes. The number of students met is an inadequate proxy for educational output so citizens are misinformed when lower per-student-credit-hour expenditures are presented as evidence of increased teaching productivity. For many teachers the pressure to increase class size is a disincentive for effective teaching. We do not know what lessening the students' individual significance at the very time it is highly important to them does to their motivation for and attitude toward learning. Almost universally they resent mass treatment in large classes. Their whole future learning may be stunted.

There are alternatives to a larger class size when confronted with rising costs. Total enrollment may be restricted to keep costs down. Cost savings may be implemented in graduate, rather than undergraduate, instruction. Priorities among programs may be established and low priority, high cost programs terminated.

Student liability suits against faculty, administrators, and the university and faculty liability suits against administrators and the university are profoundly affecting teaching programs.[1] Administrators having to defend salary, promotion, and termination decisions either in or out of court have sought ways to reduce the chance of liability suits. They have developed and used objective methods of evaluation supported by quantitative data. They have found ways to spread responsibility, such as using student and faculty evaluation data and advisory and grievance committees.

Teachers concerned with having to defend their evaluation of students have attempted to devise testing and grading schemes that reduce the grounds for student grievances; for example, using only objective tests where the quality of the answer cannot be debated.

The threat of liability suits has caused some faculty to choose teaching methods having the least chance of physical harm to students. Class trips and field work in some instances have been discontinued because of possible liability. Often the safest methods are less than the optimum learning method. State universities as a part of the state government have been immune to suit. That made the individual teacher and student fully responsible for student safety. The Kansas Supreme Court in the "Wichita State football case" (most of the football team and coaching staff were killed in a plane crash) ruled the State (University) itself could be held liable and subject to suit. That means the teacher and student, at least in Kansas, no longer stand alone on the liability issue.

Reaction to the threat of liability has caused both administrators and faculty to narrow the range of evaluation and to put all individuals as near the mean as possible. Failure to differentiate quality of instruction by faculty and quality of learning by students removes what has been an important part of the achievement incentive. Without some new incentive, the quality of both learning and instruction will decline.

The trend to quantify information and to substitute predetermined formulae for subjective judgments in resource allocation decisions in universities has several implications for undergraduate instruction. Allocating resources based on the previous year's data has the effect of perpetuating trends. If agricultural economics enrollment was up last year, this year's agricultural economics allocation is increased. Increased resources may cause expansionary efforts not justified by the market for graduates.

In my judgment, U.S. education experts are ob-

[1] Kansas State University has a suit pending resulting from an application of its faculty evaluation procedures.

sessed with determining the learning potential of students. From kindergarten through graduate school, students are given batteries of "intelligence" tests. The justification has been that the information on a student's learning ability assists the teacher and counsellor. Unless used cautiously such information can have a negative effect on the student. Telling a student his scores indicate that he will be an A, B, C, or D student may become a self-fulfilling prophecy. Aren't the results of the tests influenced by too many variables to be taken too seriously? Isn't even one chance in twenty of harming a student too great a risk to take?

In the last decade faculty, students, and administrators have greatly changed certain attitudes. Most such changes have been positive (e.g., the greater openness of the interrelationships among the three groups and the demand for recognition of individuality), but some of the changes, perhaps a small portion of the total, are disincentives to learning and teaching. The negative feeling of students and many teachers toward learning facts, classifications, and definitions has caused teachers to shy away from requiring memorization. That type of learning has little prestige, yet it is important and necessary. Many teachers prefer teaching problem solving and evaluative learning. Students, in their demand for relevancy, judge their learning experience by how problem and present-time oriented it is. Asking today's students to use the storage capacity of their brains and to memorize tabs a teacher as hopelessly old fashioned. Yet most introductory courses are learning the language and facts of that discipline. Both require memorization.

We suffer today from the learning-can-be-fun syndrome, when in fact most learning is a tedious, time-consuming effort that requires self-discipline. Techniques making learning fun are best suited to the once-over-lightly courses. In-depth study often is plain drudgery, and teachers should be honest about it. Classroom instruction that places emphasis on learning through experience rather than through reading and listening may similarly cause students to underestimate the need for self-discipline and effort in the learning process.

The "too-theoretical" criticism of some students and faculty has sent us searching for immediate relevancy. A curriculum emphasizing methods of application (how to do something) shortchanges students. What they learn from that may have higher marginal value in the first years after graduation but diminishes rapidly thereafter. Concepts, principles, and theories must be the basis for agricultural economics instruction because they are relevant longest. It is twenty to thirty years after graduation that the professional peak of a career occurs. A curriculum must assure effectiveness then as well as in the first years. Theories are for the long pull—to be used again and again, to be applied to new problems as they occur.

Students and teachers often fail to realize that students have a responsibility in setting the learning environment. Their receptivity, creativity, and evaluative skills contribute to a teacher's effectiveness. A class cannot sit back and leave the learning-teaching environment to be set by the teacher alone. What happens between the student and the teacher is important; both share in the responsibility of creating an effective learning environment.

Until agricultural economists committed to improving teaching make as rigorous a use of learning theory, teaching methods, and communication technology as research economists have made of logic, mathematics, statistics, and computer technology, there will be little real improvement. Occasionally great teaching will occur through luck, intuitive ability, and trial and error. Outstanding learning-teaching thus resulting cannot be broken into separate processes, identified, classified, recorded, and passed from teacher to teacher. The real hope for more effective learning-teaching lies in an agricultural economist who is able to integrate learning-teaching knowledge and agricultural economics so that the process of developing teaching skills can be transferred among agricultural economists and taught as an integral part of a graduate program as research methodology is today.

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A Note on Food Stamp Reform

Dennis H. Sullivan

In a recent paper, the food stamp voucher scheme was extensively analyzed in the framework of Pareto optimal redistribution (Giertz and Sullivan). This note employs a part of that analysis to compare the current scheme to one aspect of the Dole-McGovern "reform" proposal.

The present scheme sells a fixed quantity of food stamps to each recipient for a cost less than their face value.[1] The difference between the cost of the stamps and their face value is called the "bonus value" and is, in addition to any administrative expenses, the donors' cost. Figure 1 illustrates this situation on the recipient's indifference map (see Olsen). The horizontal axis measures food (F) and the vertical axis nonfood (Y), so that the slope of the budget line before subsidy ($Y'F'$) is $-P_F$, the relative price of food. The recipient is then offered the alternative of purchasing F^* food stamps, F^* being determined by family size, at a cost M^*, approximately 30% of income net of several deductions.[2] The recipient's feasible consumption set is then bounded by $Y'bcd$, where the line segment F^*c is of length $Y' - M^*$, and the "bonus value" measured in terms of food is the length of the line segment ac.

In the Dole-McGovern proposal, the "bonus value" worth of stamps is given to recipients free. In figure 1 this generates the feasible consumption set bounded by $Y'ed$, containing point c.

There are three possible outcomes. Outcome 1, illustrated by indifference curve U_1, is that the recipient optimizes by choosing a point between c and d, regardless of the scheme. Outcome 2, illustrated by U_2 and U'_2, is that the recipient chooses point c under the present scheme and some point along ec under the Dole-McGovern scheme. Outcome 3, illustrated by U_3 and U'_3, is that the recipient chooses a point along $Y'b$ under the present program (i.e., refuses to participate) and some point along ec (quite possibly e) under the Dole-McGovern scheme. Comparison of these outcomes serves to compare the welfare results of the schemes.

Outcome 1 is identical to that which would occur if the recipient were given an income transfer T^*. Thus, the recipient is indifferent among that income transfer and the two stamp schemes. The donor would also be indifferent if the actual outcome could be observed. Since the donor only observes the operation of the scheme and not its results, however, Dole-McGovern may still be preferred to an income transfer in that the recipient is known to consume at least the value of the free stamps. Also, the present scheme may still be preferred to Dole-McGovern in that the recipient is known to consume at least F^* food (see Giertz and Sullivan). The very fact that food stamps, not income, are the chosen forms of the transfer suggests that the donors have at least some concern about food consumption as opposed to low income (see Daly and Giertz).

In Outcome 2, the recipient's welfare is improved by changing to the Dole-McGovern scheme unless $MRS_{FY} = P_F$ at c, in which case the recipient is indifferent. Though the donors may for the reason stated above again prefer Dole-McGovern to an income transfer, the outcomes are identical. This suggests that the donors are unlikely to be indifferent between the current program and the Dole-McGovern scheme. In particular, if the utility interdependency is wholly goods-specific, so that the donors always prefer larger recipient food consumption to smaller (for any given donor cost), the Dole-McGovern proposal cannot possibly effect a change that meets the Pareto criterion. The recipient, after all, becomes better off precisely by reducing food consumption.

Outcome 3 is yet a different situation. The Dole-McGovern proposal removes all disincentives to participation (except, of course, any social opprobrium) and would thus doubtless increase the participation rate among eligible families. Barring the very unlikely situation that food is an inferior good, all of the newly participating families would consume more food. The problem is that the new participants run up the program's cost. Whether the benefits of increased participation exceed the additional costs is an empirical question with no obvious answer.

The main conclusion of this analysis is that the argument that the Dole-McGovern proposal will improve the welfare of the current participants at no cash cost to the Treasury is not very strong. It

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This note is a direct outgrowth of discussions with colleagues J. Fred Giertz and Philip Cotterill.

[1] Purchases of one-quarter, one-half, or three-quarters of the total allotment at a pro rata cost are legally possible for all families except those that pay by deduction from welfare payments. Only about 7% of the recipients actually elect to make fractional purchases.

[2] For historical reasons, the proportion is somewhat less than 30% at the bottom of the income scale, while the effective marginal tax rate also occasionally varies from 0.3 for smoothing purposes.

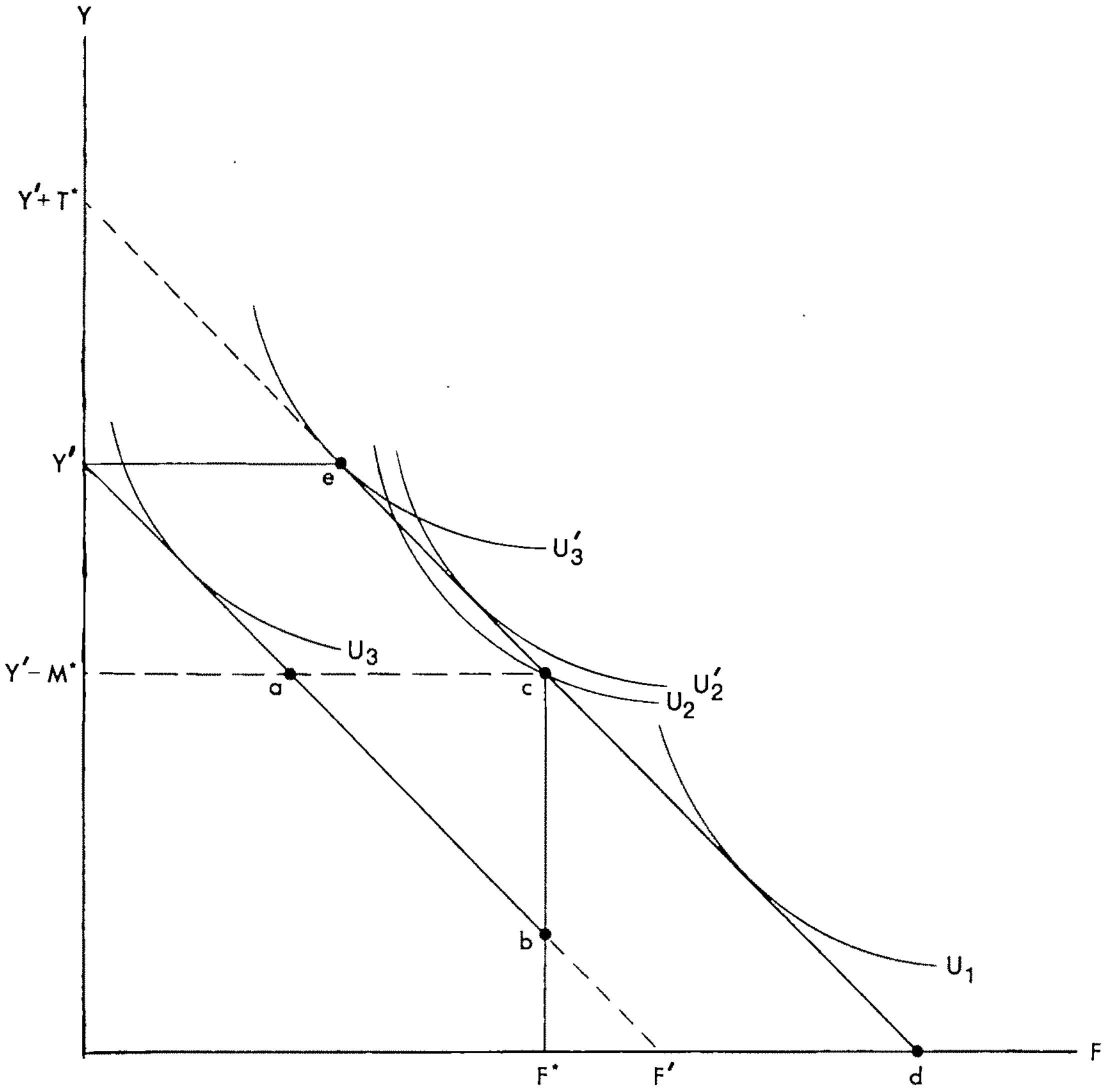

Figure 1. Outcomes of voucher schemes with various recipient indifference maps

ignores the manifest fact that the improvement in recipient welfare comes from recipients reducing their food consumption below the "nutritionally adequate" level used to establish F^* in the first place. If donors are concerned about ability to purchase an adequate diet and not about the purchase itself, food stamps should be abolished and replaced with a guaranteed income.

The real arguments for the Dole-McGovern proposal must therefore be sought elsewhere. The most obvious argument is the increase in participation. Though nonparticipating eligibles are difficult to count because of the complexity of the eligibility criteria, many believe that full participation would increase the number of recipient households by 50%. In so far as this high rate of nonparticipation indicates widespread presence of outcome 3 preference maps, rather than inertia or social stigma, the potential for increased participation is very great. The character of the new participants, however, is that they will not by preference consume a "nutritionally adequate" diet, or they would participate in the current program. We certainly may not infer that donors will be willing to subsidize small and uncertain increases in new participants' food consumption from the fact that they subsidize a large and certain level of food consumption by the current recipients. Since the Dole-McGovern scheme would actually cause some participants (outcome 2 variety) to reduce their food consumption, there is good reason to doubt that the Dole-McGovern reform reflects donor preferences, given the substantial costs.[3]

[3] The marginal conditions for the trade-off among participants, cost, and the stamp allotment are extensively discussed in Giertz and Sullivan, available from the author.

The potential for substantially increased participation suggests the existence of an additional set of interested parties: the agriculture industry. On the reasonable assumption that the increase in food consumption by outcome 3 participants exceeds any decrease by outcome 2 participants, demand for food would increase and so would factor rents to food suppliers. This external effect is not only of questionable magnitude but, unlike the interdependency between donor and recipient, is purely pecuniary and thus not a valid cause for public intervention under the usual externality criteria. Public finance texts do not determine the parameters of political coalitions, and the preferences of the farm bloc may be in practice the most important of all.

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Nutrition and Nonnutrition Components of Demand for Food Items

A. A. Prato and J. N. Bagali

Much of the concern over inadequate human diets has been directed at less developed regions such as Africa, Latin America, and the Far East. Over the past decade, there has developed a growing concern over the causes and effects of inadequate nutrition in America (Mayer, Gifft). As a result, concerned individuals have argued and worked for national policies to alleviate nutritional inadequacies. The development of such policies can be aided by a better understanding of how nutritional and nonnutritional factors affect food choices.

Current knowledge pertaining to nutritional and nonnutritional determinants of food demand is based on studies in four areas: (*a*) estimation of conventional food demand and expenditure relationships, (*b*) estimation of nutrient demand relationships, (*c*) formulation of minimum-cost human diets, and (*d*) impacts of food and nutrition programs on nutrient intake. The first group of studies provides estimates of food consumption or expenditure elasticities with respect to prices, income, and other household characteristics (Raunikar, George). In the second group are studies that estimate demand relationships for specific food nutrients by regressing the nutrient intake associated with actual food consumption on traditional price, income, and household variables (Adrian and Daniel, Kelsey). Studies in the third group concentrate on formulating diets that satisfy a variety of nutrition and nonnutrition constraints (Foytik, Langier, Balintfy, Prato). The fourth group analyzes nutrient intake of families receiving various forms of food assistance and/or nutrition education (Feaster, Madden, Gorham).

While these studies have contributed to the understanding of food purchase behavior or diet choices, the underlying relationship between diet selection and food purchases is not well understood. This lack of understanding is due in part to the absence of behavioral models and empirical studies that deal specifically with the nature and relative importance of the nutritional and nonnutritional factors that affect food demand.

The objectives of this paper are to develop a model for measuring the nutrition and nonnutrition components of demand for food products, to compare the nonnutritional demand structure of forty-two meat, poultry, and fish products over different consumer groups, and to determine how food expenditure, region, and urbanization affect the nonnutrition component of demand for these food products.

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Model Specification

The model assumes that the consumption of any food item can be decomposed into nutrition and nonnutrition components. Let $q_i^{(1)}$ represent the nutrition component, $q_i^{(2)}$ the nonnutrition component, and q_i the observed consumption of the ith food. The model specifies that $q_i = q_i^{(1)} + q_i^{(2)}$. While additivity does not allow for interaction between nutrition and nonnutrition components, it simplifies the derivation of $q^{(1)}$ and $q^{(2)}$ from q.

Let $z = Bq$, where z is an $r \times 1$ vector of nutrients actually consumed by the individual, B is an $r \times n$ matrix of nutrition coefficients that is identical over all consumers (b_{ij} is the amount of nutrient i contained in food j before cooking), and q is an $n \times 1$ observed food consumption vector. $q^{(1)}$ is defined as the food vector that provides z at minimum cost, i.e., $z = Bq^{(1)}$ and $p'q^{(1)}$ is a minimum so that $p'q \geq p'q^{(1)}$. Alternative specifications of $q^{(1)}$ are possible. For example, $q^{(1)}$ could be defined as the food vector that provides the recommended dietary allowances (RDA's) of nutrients established by the National Research Council. While the RDA specification for $q^{(1)}$ is appealing from a nutrition standpoint, it is less satisfactory in a behavioral sense because not all consumers know the RDA's. Moreover, consumers may not attempt to achieve their RDA's even if they have knowledge of them.

If $q = q^{(1)}$, the consumer is selecting those foods that provide z at minimum cost. This reflects nutritional efficiency in food choices. If $q \neq q^{(1)}$, it is possible for the nonnutrition component of a food item ($q_i^{(2)} = q_i - q_i^{(1)}$) to be positive or negative, which implies nutritional inefficiency. This means the nutrients were not obtained from the most economical (minimum-cost) foods.

Two hypotheses are tested. The first hypothesis is that nutritional inefficiencies exist in consumers' food choices. The second hypothesis is that nutritional inefficiency increases with respect to residual food expenditure ($e^{(2)} = m_f - p'q^{(1)}$, where m_f is total food expenditure).

The first hypothesis is tested by estimating $e^{(2)}$ for different consumer groups and observing the frequency with which it is positive or negative. The second hypothesis is tested by estimating an Engel function for each food item. This function relates residual expenditure on the ith food item ($e_i^{(2)} = p_i q_i^{(2)}$) to total residual food expenditure ($e^{(2)}$). A positive relationship supports the second hypothesis.

Food items can be aggregated into four major groups: (*a*) meat, poultry, and fish, (*b*) vegetables and fruits, (*c*) milk, cream, and cheese, and (*d*) other food items. In 1965, these groups accounted for 36%, 18%, 13%, and 33% of total household food expenditure in the United States (USDA). The nutrition coefficients matrix (B) was only available for the first group (as defined in the 1965 USDA Household Food Consumption Survey). For this reason the empirical analysis was limited to the forty-two food items in the red meat, poultry, and fish group. The spring sample of households was used because it is more representative of annual U.S. food consumption patterns and three times larger than samples for the other seasons (7,500 versus 2,500). The survey reports average quantity consumed and expenditure per household per week on each of forty-two items in four regions, Northeast (NE), North Central (NC), South (S), and West (W), in three urbanizations, urban (U), rural nonfarm (RNF), and rural farm (RF), and in several income classes.

Procedure

Nutrient intake vectors contained eleven nutrients: z_1 = energy (calories), z_2 = protein (grams), z_3 = fat (grams), z_4 = carbohydrates (grams), z_5 = calcium (milligrams), z_6 = iron (milligrams), z_7 = vitamin A (international units), z_8 = thiamine (milligrams) z_9 = riboflavin (milligrams), z_{10} = niacin (milligrams), and z_{11} = ascorbic acid (milligrams).

Letting j denote region, k urbanization, and l income class, $\bar{q}_{jkl}$ is the average food consumption vector and $\bar{e}_{jkl}$ is the average food expenditure vector for the jkl class. The average price vector $\bar{p}_{jkl}$ was computed by dividing each element of $\bar{e}_{jkl}$ by the corresponding element of $\bar{q}_{jkl}$. All consumption, expenditure, and nutrient intake vectors were converted to per capita figures using the average family size (r_{jkl}), i.e., $\tilde{q}_{jkl} = \bar{q}_{jkl}/r_{jkl}$, $\tilde{e}_{jkl} = \bar{e}_{jkl}/r_{jkl}$, and $\tilde{z}_{jkl} = \bar{z}_{jkl}/r_{jkl}$. The nutrition components were obtained by solving the following linear programs for $\tilde{q}_{jkl}^{(1)}$: min $\bar{p}'_{jkl}\,\tilde{q}_{jkl}^{(1)}$ subject to $B\tilde{q}_{jkl}^{(1)} \geq \tilde{z}_{jkl}$ and $\tilde{q}_{jkl}^{(1)} \geq 0$, where $\tilde{z}_{jkl} = B\tilde{q}_{jkl}$ is the vector of consumed nutrients. Since the data contained 104 region-urbanization income (RUI) classes, the linear programming models yielded 104 solution vectors. These were then used to derive the nonnutrition component and residual expenditure for each RUI class, namely, $\tilde{q}_{jkl}^{(2)} = \tilde{q}_{jkl} - \tilde{q}_{jkl}^{(1)}$ and $\tilde{e}_{jkl}^{(2)} = \bar{p}'_{jkl}\,\tilde{q}_{jkl}^{(2)}$.

Two statistical models were used to analyze the nonnutrition component. The first model is obtained by constrained maximization of a Stone-Geary utility function (Stone, Geary). This yields the following linear expenditure system after correction for induced heteroscedasticity (Kmenta, pp. 256–58):

$$\tilde{y}_{ijkl}^{(2)} = \beta_{ijk}\,\tilde{m}_{jkl}^{(2)} + v_{ijkl}, \tag{1}$$

where $\tilde{y}_{ijkl}^{(2)} = \sqrt{n_{ijkl}}\,\tilde{e}_{ijkl}^{(2)}$, n_{ijkl} = the number of families consuming good i in each RUI class, and $\tilde{m}_{jkl}^{(2)} = \sum_{i=1}^{42} \tilde{y}_{ijkl}^{(2)}$. Equation (1) can be fitted by ordinary least squares to obtain an estimated residual expenditure slope for each of the forty-two meat, poultry, and fish items in each region-urbanization class (504 slopes in total).

The second statistical model consists of a single equation for each commodity that combines the observations over all region-urbanization classes. The following analysis of covariance model is used (Scheffé, pp. 207–13):

$$\tilde{y}_{ijkl}^{(2)} = \mu_i + \alpha_{ij} + \gamma_{ik} + \beta_i\tilde{m}_{jkl}^{(2)} + \epsilon_{ijk} + v_{ijkl}, \tag{2}$$

where μ_i is the overall mean, α_{ij} is the region effect, γ_{ik} is the urbanization effect, β_i is the residual expenditure slope, ϵ_{ijk} is an interaction term, and v_{ijkl} is a disturbance term assumed to be spherical normal. Estimation of equation (2) for each of the forty-two food items was based on 104 observations.

Results

Linear programming was used to obtain the minimum-cost diet (nutrition component) for each of 104 RUI classes. Table 1 gives the twenty-four meat, poultry, and fish items that entered these diets most frequently. Except for sirloin steak, the items conform to a priori expectations concerning economical and nutritious meat items. Regression results based on equation (1) indicate that with the exception of six items the β_{ijk} (or simply β) coefficients (estimated residual expenditure slopes) are positive. With the exception of a few veal, lamb, and poultry items, between one-half and two-thirds of the β coefficients for each commodity (when estimated for all region-urbanization categories, for regions over all urbanizations, and for urbanizations over all regions) are statistically significant at the 5% level. Elasticities computed from the β coefficients are generally greatest for beef products, which is consistent with results obtained in other studies (George). Elasticities for cured ham, bacon, and fresh pork chops are relatively high, although somewhat below elasticities for ground beef and round steak.

Except for salt pork, the remaining pork products

Table 1. Economically Nutritious Meat, Poultry, and Fish Items Based on Least-Cost Diets[a]

Food Item	Frequency with Which Item Entered Least-Cost Diets (104 Possible)	Rank Based on Relative Frequency
Liver	104	1
Salt pork	90	2
Sirloin steak	79	3
Salmon, canned	75	4
Lamb, ground	20	5
Other variety meat	20	5
Turkey	19	6
Chicken	18	7
Fish, frozen	9	8
Other fresh pork	9	8
Bacon	5	9
Beef, ground	3	10
Beef stew	3	10
Ham	3	10
Other cured pork	3	10
Beef roast, rump	2	11
Other raw beef	2	11
Pork loin	2	11
Veal, ground	2	11
Beef, canned	1	12
Frankfurters	1	12
Lunch meat, canned	1	12
Sausage	1	12
Tuna, canned	1	12

[a] An economically nutritious food is one that entered at least one of the 104 minimum cost diets computed for the 104 observations.

have positive but small β coefficients. Coefficients for lunch meats are positive and rather high for uncanned meats and frankfurters. The coefficients for chicken are greater than for the more popular beef items, while coefficients for turkey are negative except in two RUI classes. Fresh fish and canned tuna have the highest β coefficients in the fish group. Canned salmon exhibits negative β coefficients.

Results for the minimum-cost diets and the regression analysis based on equation (1) support the hypothesis that nutritional inefficiency exists in food consumption. Evidence consists of (*a*) the large number of popular food items, especially beef and chicken, that do not appear to be economically nutritious foods (table 1), (*b*) the fact that residual expenditure ($e^{(2)}$) is positive for all 104 consumer groups analyzed, and (*c*) the predominance of positive and significant β coefficients. The latter finding also supports the second hypothesis because positive and significant β coefficients imply that the nonnutrition component increases with respect to residual expenditure.

Results for equation (2) show that β_i (residual expenditure slope) is positive and significant (5% or less) for all four beef steak items; chuck and ground beef; pork chops, pork loin, and ham; veal chops; uncanned lunch meat; chicken and canned tuna. Region and/or urbanization effects are statistically significant for round steak, porterhouse, and other steak; ground beef; pork chops and ham; veal chops; and fresh fish. Interaction effects are statistically significant for ground beef, salt pork, veal chops, and fresh fish.

Table 2 reports the frequency and rank of urbanization (γ_k) and region (α_j) effects for seven major meat groups composed of the original forty-two items. Frequencies show the proportion of estimated main effects that are positive. A positive (negative) main effect implies that the nonnutrition component for that region or urbanization is above (below) the overall mean nonnutrition component (μ). For ease of interpretation, interaction effects are ignored.

Nonnutrition components for beef and pork are highest in urban areas and lowest in rural nonfarm areas. Beef's component is highest in the West and lowest in the South, while the opposite holds for pork. For the remaining food groups, excluding poultry, the nonnutrition component is greatest in urban areas and lowest in rural farm areas. Veal and lamb components are greatest in the Northeast. Variety meats are highest in urban and rural nonfarm areas and the West. Fish is highest in urban areas and the Northeast. In summary, rankings show that urban areas have the highest nonnutrition component over all food groups except poultry. Regional differences are less systematic. However, the Northeast or West has the highest component for all groups except pork.

Table 2. Relative Importance of Nonnutrition Component by Region, Urbanization, and Food Group

	Urbanization Effect			Region Effect			
Food Group	Urban	Rural Nonfarm	Rural Farm	NE	NC	S	W
			Frequency[a], Rank[b]				
Beef	$\frac{9}{13}$, 1	$\frac{2}{13}$, 3	$\frac{10}{13}$, 2	$\frac{7}{13}$, 2	$\frac{7}{13}$, 2	$\frac{6}{13}$, 3	$\frac{11}{13}$, 1
Pork	$\frac{7}{10}$, 1	$\frac{1}{10}$, 3	$\frac{6}{10}$, 2	$\frac{4}{10}$, 3	$\frac{5}{10}$, 2	$\frac{7}{10}$, 1	$\frac{3}{10}$, 4
Veal	$\frac{3}{3}$, 1	$\frac{1}{3}$, 2	0,3	$\frac{3}{3}$, 1	$\frac{2}{3}$, 2	0	0
Lamb	$\frac{2}{3}$, 1	$\frac{1}{3}$, 2	$\frac{1}{3}$, 3	$\frac{3}{3}$, 1	0,3	$\frac{1}{3}$, 2	$\frac{3}{3}$, 2
Variety meats	$\frac{3}{6}$, 1	$\frac{3}{6}$, 1	$\frac{2}{6}$, 2	$\frac{3}{6}$, 2	$\frac{3}{6}$, 2	$\frac{3}{6}$, 2	$\frac{5}{6}$, 1
Poultry	0,3	$\frac{2}{3}$, 1	$\frac{1}{3}$, 2	$\frac{1}{3}$, 3	$\frac{1}{3}$, 3	$\frac{2}{3}$, 2	$\frac{3}{3}$, 1
Fish	$\frac{3}{5}$, 1	$\frac{2}{5}$, 2	$\frac{2}{5}$, 2	$\frac{4}{5}$, 1	$\frac{1}{5}$, 3	$\frac{3}{5}$, 2	$\frac{3}{5}$, 2

[a] Frequency of positive effects.
[b] According to frequency of positive effects in food group.

Policy Implications and Limitations

Knowledge of the nutrition and nonnutrition components of the forty-two meat, poultry, and fish items analyzed here can be helpful in the design and administration of programs to alleviate nutritional deficiencies. Based on these components, it is possible to classify meat items according to the relative importance of their nutrition and nonnutrition components. Consumption of those items having a relatively large nutrition component (as demonstrated by the linear programming solutions) should be encouraged, while consumption of items having a relatively large nonnutrition component should be discouraged.

In cases where a family is receiving nutrition education, the program aide could encourage the use of foods having important nutrition components (as defined herein). Results for the forty-two food items analyzed in this study suggest that the ability of income-enhancing food programs, e.g., food stamps, to increase the intake of high nutrition component foods may be quite limited. In particular, even though higher income families spend more on food, they do not necessarily have nutritionally better diets because the additional income is spent on foods having high nonnutrition components. The evidence also shows that the relative economic efficiency with which additional food nutrients are acquired decreases with respect to food expenditure.

For the majority of U.S. households that do not participate in food and nutrition programs, alternative approaches to reducing nutrient deficiencies are required. One possibility is to fortify and enrich those foods having significant nonnutrition components. This approach essentially boosts the nutrition component of foods favored for nonnutritional reasons. Changing the methods of processing and preparing foods could enhance their nutritional component.

The method and analysis presented here have certain limitations. The linear expenditure system is better suited to broad complementary categories of commodities than to individual food items. Moreover, the linear Engel curves derived from this expenditure system may not be appropriate over wide income or food expenditure ranges. Many of the socioeconomic variables that are likely to affect the nonnutrition component could not be accounted for in this study due to the aggregated nature of the data. Use of less aggregated household data, e.g., data on individual families, would permit a more comprehensive analysis of nonnutrition components.

Additivity of nutrition and nonnutrition components is somewhat restrictive because it precludes interaction effects. Significant interactions would diminish the appropriateness of the method and the accuracy of the results. The composition of the nutrition component is also restrictive because it includes only nutrients for which recommended intake levels have been established. Other nutritional motivations such as bulk and variety of diet could be incorporated into the model if standards pertaining to these factors were available.

Finally, the empirical analysis is based on only forty-two meat, poultry, and fish items. Exclusion of other food items leads to nutrition components that are suboptimal with respect to all foods; that is, the consumed nutrients are not really obtained in the most efficient manner because food selections

outside the meat-poultry-fish group are not permitted. Accordingly, the empirical analysis should not be judged in terms of its accuracy but rather as an example of how to apply the theoretical model and interpret results. Clearly, the analysis needs to be expanded to all food items. Despite these limitations, this paper presents one approach to analyzing the simultaneous effects of nutrition and nonnutrition factors on the food and diet choices of U.S. households.

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Possible Implications of Voids in USDA Cattle Slaughter Data

Kendell Keith and Wayne D. Purcell

An important service provided by the U.S. Department of Agriculture is the gathering and publication of production, price, and related data on major agricultural commodities produced and marketed in the United States. Much of the agricultural research conducted in land grant universities, branches within the USDA, and private industry is based on such data. Since commodity analysis is a major justification for gathering and publishing the data, the extent to which the published series match the data needs of analysts should be continually examined.

The primary purpose of this note is to discuss a void in the set of published cattle and calf slaughter data that seriously restricts fundamental analysis of the cycle in cattle numbers. Measurement of the response by beef producers to changes in the level of cattle prices is first complicated by the fact that beef and dairy slaughter are reported only as an aggregate figure. The analytical value of published slaughter series is hampered even more by the absence of a breakdown of nonfederally inspected slaughter into the four classes of cattle. Three analyses are employed to demonstrate that the actual magnitude of cow slaughter and interyear variation in cow slaughter are well disguised in existing data. Three areas of research are then outlined to demonstrate how the missing data series limit analysis.

Presently, monthly slaughter series are published for the following categories: (*a*) total commercial cattle slaughter, (*b*) total federally inspected cattle slaughter, (*c*) federally inspected cattle slaughter subdivided into four classes—steers, heifers, cows, and a class called bulls and stags, (*d*) commercial calf slaughter, and (*e*) federally inspected calf slaughter. To persons unfamiliar with livestock slaughter data, omissions in the reported data of potential importance to analysts are not obvious. Slaughter data not contained in these categories are percentages of male and female calf slaughter and commercial nonfederally inspected cattle slaughter subdivided into the classes of steers, heifers, cows, and bulls and stags.

Since 1944, federally inspected slaughter has been published for the identified classes of steers, heifers, cows, and bulls and stags. Commercial slaughter not under federal inspection has never been separated into classes. To estimate total commercial slaughter in the various classes, most researchers in the past have assumed that the breakdown of federally inspected slaughter is a usable approximation of the breakdown of total commercial slaughter. Because federally inspected cattle slaughter currently makes up about 90% of all commercial cattle slaughter, any estimation error attributable to the assumed comparability between total commercial and federally inspected slaughter would appear to be small. The error in estimation by the technique described, however, is likely much larger than most researchers presume. Considerable evidence suggests total commercial cow slaughter is underestimated by applying the percentage breakdown of federally inspected slaughter to nonfederally inspected slaughter.

But an accurate measure of cow slaughter appears to be the one series most essential to productive research dealing with cattle numbers and the beef cycle. The total number of cows slaughtered is a determinant of future cow inventories, which in turn measure slaughter potential and the phases in each recurring cattle cycle. For decision purposes, therefore, accurate measures of interyear developments in cow slaughter become very important.

Because total commercial cow slaughter has never been reported, the hypothesis that cow slaughter is the principal component of cattle slaughter in plants not under federal inspection is difficult to test. In the following section the results of three separate analyses are presented. None of the analyses constitute a conclusive test of any hypothesis as to the level of cow slaughter in nonfederally inspected plants. But taken in combination, the findings offer strong indication that cow slaughter as a percentage of total slaughter is substantially larger in nonfederally inspected plants.

Cow Slaughter Calculated from Replacement Heifer Inventories

Beginning in 1965, the USDA modified several of the data series on cattle inventories. Two additions to the published inventory series were heifers intended for replacement in the beef cow herd and heifers for replacement in the milk cow herd. By making a few reasonable and defensible assump-

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tions, figures on replacement heifers can be utilized in calculating estimates of cow slaughter.

During a recent nine-year period, January 1965 to January 1974, the inventory of cows on farms increased 5.513 million head (USDA). Assuming an annual cow death loss of 2.7%, total cow deaths in the years 1965–73 were 11.931 million head.[1] The total number of heifers held back for herd replacement for the nine-year period was 94.078 million head. Assuming over the nine-year interval the sum of the annual differences between heifers intended for replacement and actual replacement heifers entering the herd was 0, equation (1) may be used to approximate total commercial cow slaughter for the period:

$$\text{(1)}\quad \begin{array}{lcl} \text{(Heifers)} - \text{(Growth)} & & \\ 94.078 \; - \; 5.513 & & \\ \quad - \text{(Deaths)} & = & \text{(Cow Slaughter)} \\ \quad - \; 11.931 & = & 76.634. \end{array}$$

Total federally inspected cow slaughter for the nine-year period was 52.150 million head. Estimated nonfederally inspected cow slaughter would therefore be 24.484 million head (76.634 − 52.150).

Total commercial slaughter that was not federally inspected was 43.433 million head for the January 1965 through December 1973 period. Using the estimate of 24.484 million head, an estimated 56.4% of the commercial slaughter not under federal inspection was cow slaughter.

Cow Slaughter from Cow Inventories and Replacement Rates

The analysis used above is not applicable for any period before 1965, the year in which the published series on replacement heifers were begun. Another method of estimating cow slaughter over a period of several years that uses a different set of assumptions can be developed. Equations (2) and (3) present the relationships:

$$\text{(2)}\quad \text{Milk Cow Slaughter}_{t-1} = \left[\frac{(MCH_{t-1} - MCH_t)}{2\, MCH_{t-1}} + MRR - 0.027\right] MCH_{t-1},$$

and

$$\text{(3)}\quad \text{Beef Cow Slaughter}_{t-1} = \left[\frac{(BCH_{t-1} - BCH_t)}{2\, BCH_{t-1}} + BRR - 0.027\right] BCH_{t-1},$$

where MCH = milk cow herd, BCH = beef cow herd, MRR = estimated milk replacement rate needed to maintain a constant herd size, BRR = estimated beef replacement rate needed to maintain a constant herd size, and t = time (years).

[1] The cow death estimate of 2.7% allows for a maximum of a 1% death loss in mature cattle other than cows during the period. In comparison, a lower estimate of 2.4% results in an average of a 1.4% death rate in other cattle, while a higher estimate of 3% is associated with a 0.56% death estimate in cattle other than cows.

The only major assumption used in equations (2) and (3) was one concerning the nature of growth or decline in cow inventories. The asserted relationship is that increases (decreases) in the inventory of cows is caused by equal proportions of decreased (increased) cow slaughter and increased (decreased) holdings of replacement heifers. This assumption is less defensible than those utilized in the previous analysis. The two equations are not likely to furnish an accurate measure of cow slaughter over a short interval. But, for the time period of study in this analysis, the assumption is reasonable and provides a means to generate useful estimates.

The death rate of cows was again assumed to be 2.7% per year. Average replacement rates required to maintain a constant herd size were calculated on the basis of heifers intended for replacement during 1965–74. For beef cattle the replacement was 0.1611 per year, and for dairy cattle the replacement rate was 0.2935 per year. Given that these two figures were estimates for the 1965–74 period and might not be particularly applicable to the 1950–64 period, other possible replacement rates were considered and used in equations (2) and (3) to estimate total commercial cow slaughter for the fifteen-year period. Table 1 displays the results of the slaughter estimations.

Total commercial cattle slaughter for the 1950–64 period was 361.048 million head of which 86.499 million head were not federally inspected. Federally inspected cow slaughter for the period was 74.120 million head. Given the possible range on total commercial cow slaughter of 109.13 to 129.51 million head, a range of 40.5 to 64.0 can be placed on cows as a percentage of total nonfederally inspected slaughter.

Relation of Federally Inspected and Nonfederally Inspected Slaughter

As a final test to determine if cow slaughter is the major component of nonfederally inspected commercial slaughter, several equations were estimated. Annual federally inspected cow, steer, and heifer slaughter were tested to see how well they explained year-to-year variations in nonfederally inspected slaughter. Regressions were run on annual time-series data from 1950 to 1973:

Table 1. Estimated Commercial Cow Slaughter Given Alternative Average Replacement Rates, 1950–64

	Milk Replacement Rate		
Beef Replacement Rate	0.29	0.27	0.25
	---- million head ----		
0.16	129.51	123.07	116.63
0.15	125.76	119.32	112.88
0.14	122.01	115.57	109.13

$$(4)\quad SLAT = \underset{(0.733)}{5037.29 + 0.1957\, STR} \underset{(1.23)}{- 158.68\, TIME}, \quad R^2 = 0.24 \quad S = 906.12;$$

$$(5)\quad SLAT = \underset{(0.494)}{6155.13 + 0.1886\, HEIF} \underset{(0.97)}{- 132.11\, TIME}, \quad R^2 = 0.23 \quad S = 912.35;$$

and

$$(6)\quad SLAT = \underset{(2.52)}{3988.71 + 0.4677\, COW} \underset{(3.36)}{- 82.84\, TIME}, \quad R^2 = 0.40 \quad S = 804.01;$$

where $SLAT$ = commercial slaughter not federally inspected, STR = federally inspected steer slaughter, $HEIF$ = federally inspected heifer slaughter, COW = federally inspected cow slaughter, $TIME$ = time (numbers 1 to 24 used to take into account the declining nonfederally inspected slaughter), and S = standard error of estimate. Numbers in parentheses are estimated t-statistics.

None of the estimated equations have good statistical fits, but the coefficients and t-test statistics appear to support the two previous analyses. Federally inspected steer and heifer slaughter were not statistically significant in the equations tested. In equation (6) federally inspected cow slaughter is significant at the 0.05 level as an explanatory variable. The coefficient on the COW variable indicates that any change in federally inspected cow slaughter is positively associated with a change of approximately half the magnitude in nonfederally inspected commercial slaughter. This testing procedure, although not conclusive, gives strong indication that cow slaughter comprises a substantial percentage of nonfederally inspected commercial slaughter.

Cow Slaughter Data: Key to the Cycle

Cattle price levels in 1974, resembling the conditions of the early 1950s, emphasized again the need for a better understanding of the cattle cycle. The recurrence of the cattle cycle is due in part to decisions at the cow-calf level of production. Cow-calf producers simply act in a rational profit-maximizing manner given the information base they use in making decisions to increase or decrease herd size. Better price-outlook information could diminish the severity of peaks and troughs in the cycle and thus reduce the risk involved in raising cattle.

For persons who have not attempted practical applications, such as outlook analyses using available slaughter data, specific problems created by the lack of data on nonfederally inspected slaughter go unrecognized. To better demonstrate the benefits that could result from more precise data on nonfederally inspected slaughter, three areas of analysis of the cattle cycle are discussed. Examination of these areas in more detail should demonstrate that the lack of data on nonfederally inspected cow slaughter is a major barrier to effective analysis of the cattle cycle.

An excellent approach to gaining an understanding of the relationships involved in the cattle cycle is to trace cattle inventories to their eventual destinations. However, such a rudimentary analysis as this is impossible without the use of two assumptions, both of which are at best difficult to defend. First, the relative amounts of male and female calf slaughter must be determined in some subjective manner. The percentages of each class slaughtered in nonfederally inspected facilities are unknown. The statistical results presented earlier helped show that this latter variable is not easily estimated. With no accurate method of tracing inventory data to slaughter or death, few if any measures exist to verify whether reported inventories are at levels they should approximate given slaughter during the previous year.

A second area of analysis impeded by the data void is the nature of growth and decline in cow numbers. Through the phases in the cattle cycle, the proportion of total growth comprised of increased heifer holdings is simply not known to an acceptable degree of accuracy. A comparison of recent levels of cow slaughter with those during 1953–54 suggests that a significant inverse relationship may exist between the average age of the beef cow herd and the time lag involved between a price decline and reduced inventories. A test to confirm this relationship would necessarily include a method of estimating the average age of the cow herd. The lack of adequate data forces any approach that is tried to rely on largely indefensible assumptions about the makeup of nonfederally inspected slaughter.

A third area of research is closely related to available knowledge on herd growth. More orderly growth in future beef cow numbers is not an impossible task. Relatively stable growth patterns in both U.S. population and per capita income simplify projections of future levels of beef demand. To meet future demand and maintain more stability in growth, information regarding the number of replacement heifers required for various growth rates is needed. Useful estimates of required holdings of heifers are difficult to achieve without an acceptable measure of total commercial cow slaughter.

Given present knowledge of the percentages of each class of cattle in commercial slaughter, no technique exists to verify the accuracy of either inventory or slaughter data. Also, no acceptable means is available to describe the nature of growth in cow numbers, which implies inadequate resources with which to analyze the cattle cycle.

Thus, analysts are unable to verify or quantify many of the assumed relationships believed to be important causal factors of the cycle. Given the situation, only vague notions of expected behavioral responses by cattle producers to given price levels or changes in price can be developed.

The decline of nonfederally inspected slaughter as a percentage of total slaughter suggests that the importance of knowing its makeup by classes is diminishing with time. The rate of decline in the nonfederally inspected percentage has slowed substantially, however, and has even shown a slight increase since 1973. A continuation of the present system of reporting slaughter numbers will likely create perplexing problems for analysts for many years to come.

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Acreage Response to Policy Variables in the Prairie Provinces

Karl D. Meilke

Several recent attempts have been made to estimate the acreage response of Canadian wheat, oats, and barley to changes in price (Capel, Schmitz, Schmitz and Bawden, Missiaen and Coffing). The estimated elasticities of wheat acreage response to wheat price have been found to vary from 0.42 to 0.88 in the short run and from 0.62 to 1.30 in the long run. The wide range of elasticity estimates are due in part to the different definitions of wheat price employed in each study.[1] Capel used the Canadian Wheat Board international wheat agreement price for No. 2 northern wheat during March at Fort William. Schmitz used the latest final price (including the final payment) prior to seeding, while Missiaen and Coffing used the farm price of wheat lagged one year as did Schmitz and Bawden. Since there seems to be disagreement about which price farmers respond to, a short discussion of Canadian grain pricing practices may be useful.

The Canadian Wheat Board is a crown corporation with monopoly control over the marketing of wheat, barley, and oats produced in the Prairie provinces and the Peace River area of British Columbia. The board pays producers an initial payment for grain delivered to it, pools the grain for sale, and returns the profits from the pool to producers in a final payment. The initial payment is a floor price with the Canadian government making up the difference if the average selling price is below the initial payment (Missiaen and Coffing).[2] Initial plus adjustment payments for wheat have ranged from \$1.40 to \$3.75 per bushel between the 1949–50 and 1973–74 crop years.[3] Proceeds over and above the initial plus adjustment payment are paid to producers in a final payment made approximately eighteen to twenty-four months after the crop is planted. Final plus interim payments for wheat since 1949–50 have ranged from nothing on the 1968–69 pool to 82.8¢ per bushel on the 1973–74 pool.[4] Barley and oats are handled in a similar manner to wheat, although in separate pools.

Given these pricing practices of the Canadian Wheat Board, it is hypothesized that grain producers react to two different prices in determining what crops and how much to plant: the initial plus adjustment payment, which has been quite stable, and the final plus interim payment.[5] None of the acreage response studies mentioned earlier differentiate between farmers' reactions to changes in initial payments and changes in final payments.

This paper reports on a study undertaken to determine if Prairie farmers react differently to changes in initial and final payments in making their wheat, oats, and barley planting decisions. To test this hypothesis, acreage response functions are estimated using initial and final payments as separate variables. These functions are then compared in terms of expected signs, goodness of fit, and estimated elasticities to response functions incorporating only one price variable. If farmers do react differently to changes in initial and final payments, this information can be used to influence the acreage devoted to wheat, oats, and barley grown in the Prairie provinces. An example is given in the paper of how initial payments can be varied in order to achieve acreage targets.

The Model

Acreage response functions of the following general form (equations (1) and (2)) are estimated for wheat, oats, and barley grown in the Prairie provinces:

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[1] The only paper presenting quantitative estimates of barley and oats acreage response is Missiaen and Coffing, and the estimated acreage response elasticities are based on statistically insignificant price coefficients.

[2] It should be noted that in the fall of 1973 a new Canadian feed-grain policy was implemented. Under the new policy it is no longer necessary for Prairie grain producers to sell their grain to the Canadian Wheat Board, although this option is still available. With the new feed-grain policy, the acreage response of farmers to changes in initial payments may be different than it has been during the study period. For a discussion of this program, see the report by the Canada Grains Council.

[3] In the empirical analysis, the initial payment variables include adjustment payments in years when an adjustment was made. Adjustments (increases) in the initial payment are normally made in the spring of the year when it is clear that selling prices will be well above the initial payment level announced at the start of the crop year. Adjustment payments are retroactive to the beginning of the crop year and have been made in seven out of the twenty-five years under study for wheat, eight for barley, and four for oats.

[4] Interim payments are advances on the final payment and have been made quite frequently for wheat, i.e., ten out of the twenty-five years under study. In the empirical analysis interim payments are added to the final payment for that year.

[5] In the remaining discussion the terms initial and final payments refer to variables defined as initial plus adjustment payments and final plus interim payments.

Table 1. Ordinary Least Squares Estimates of Prairie Acreage Response Functions

Eq. No.	Dep. Var.	Constant	IP_w^{t-1}	IP_b^{t-1}	IP_o^{t-1}	FP_w^{t-1}	FP_b^{t-1}	FP_o^{t-1}	Z_1^{t-1}	Z_2^{t-1}	PL^{t-1}	D_{70}	Lagged Dep. Var.	$\bar{R}^2$	h
(3)	A_w^t	10.25	7.98	−16.00		6.89	6.05		9.37			−12.09	0.48	0.92	1.01
		(4.11)	(2.42)	(−3.17)		(3.20)	(−1.86)		(2.64)			(−8.83)	(6.89)		
	SRE		0.53	−0.69		0.08	−0.05		0.24						
	LRE		1.01	−1.32		0.15	−0.09		0.47						
(4)	A_b^t	1.49	−8.47	11.83		−3.59	6.75		−7.38		0.03		0.44	0.79	0.06
		(0.64)	(−2.64)	(2.60)		(−1.89)	(2.19)		(−2.42)		(3.63)		(3.13)		
	SRE		−1.65	1.50		−0.12	0.15		−0.57		1.08				
	LRE		−2.95	2.68		−0.22	0.28		−1.01		1.93				
(5)	A_o^t	5.10	−2.46		7.27	−2.05		3.79		−7.40			0.64	0.63	2.72
		(2.52)	(−2.61)		(1.92)	(−1.77)		(1.85)		(−2.58)			(4.19)		
	SRE		−0.65		0.78	−0.09		0.10		−0.63					
	LRE		−1.81		2.17	−0.26		0.27		−1.75					

Eq. No.	Dep. Var.	Constant	P_w^{t-1}	P_b^{t-1}	P_o^{t-1}	Z_1^{t-1}	Z_2^{t-1}	PL^{t-1}	D_{70}	Lagged Dep. Var.	$\bar{R}^2$	h
(6)	A_w^t	5.83	4.51	−7.81		12.83			−11.01	0.49	0.87	0.82
		(2.69)	(2.06)	(−2.43)		(3.76)			(−7.14)	(6.04)		
	SRE		0.35	−0.40		0.33						
	LRE		0.69	−0.78		0.65						
(7)	A_b^t	1.91	−3.66	4.67		−5.79		0.02		0.48	0.77	1.09
		(0.88)	(−2.04)	(1.83)		(−2.18)		(3.21)		(3.31)		
	SRE		−0.84	0.70		−0.44		0.88				
	LRE		−1.62	1.35		−0.86		1.70				
(8)	A_o^t	6.07	−2.15		4.68		−7.97			0.71	0.65	2.42
		(3.87)	(−3.12)		(2.76)		(−2.96)			(3.31)		
	SRE		−0.67		0.62		−0.67					
	LRE		−2.31		2.13		−2.31					

Sources: Canadian Wheat Board, and Statistics Canada.
Note: variable definitions: A_i^t = acreage harvested in Prairie provinces (million acres); IP_i^{t-1} = initial plus adjustment payments ($/bu.); FP_i^{t-1} = final plus interim payments ($/bu.); Z_1^{t-1} = marketings of wheat divided by on-farm carry-in plus production of wheat; Z_2^{t-1} = yield of wheat divided by the yield of oats per acre; PL^{t-1} = an index of Canadian Farm Products (animal) prices during April through March (1935–39 = 100, where $i = w$, wheat; $i = o$, oats, $i = b$, barley; and t and $t - 1$ = time periods.

$$(1)\quad A_i^t = f_1(IP_i^{t-1}, IP_j^{t-1}, FP_i^{t-1}, FP_j^{t-1}, Z_i^{t-1}, A_i^{t-1}, \epsilon_{i1}^t),$$

and

$$(2)\quad A_i^t = f_2(P_i^{t-1}, P_j^{t-1}, Z_i^{t-1}, A_i^{t-1}, \epsilon_{i2}^t),$$

where A_i^t = acreage of crop i in year t, IP_i^{t-1} = initial payment plus adjustment payment for crop i in year $t - 1$, IP_j^{t-1} = initial payment plus adjustment payment for competing crop j in year $t - 1$. FP_i^{t-1} = final payment plus interim payment for crop i in year $t - 1$, FP_j^{t-1} = final payment plus interim payment for competing crop j in year $t - 1$, Z_i^{t-1} = other lagged variables that may shift the acreage response curve, $P_i^{t-1} = IP_i^{t-1} + FP_i^{t-1}$, $P_j^{t-1} = IP_j^{t-1} + FP_j^{t-1}$, and $A_i^{t-1} = A_i^t$ lagged one year.

In equation (1) the influence of initial and final payments are included as separate variables, while in equation (2) they are combined into a single measure of price.[6] In general we would expect the coefficients on variables IP_i^{t-1}, FP_i^{t-1}, A_i^{t-1}, and P_i^{t-1} to be positive, while the coefficients of IP_j^{t-1}, FP_j^{t-1}, and P_j^{t-1} would be negative. Variables employed in the empirical analysis that are identified as Z_i^{t-1} above include livestock prices (PL^{t-1}), marketings of wheat as a percentage of production plus on-farm carry-in lagged one year (Z_1^{t-1}), and the yield of wheat relative to the yield of oats lagged one year (Z_2^{t-1}).

Including a lagged dependent variable among the list of independent variables in equations (1) and (2) is equivalent to assuming a geometric distributed lag model. Nerlove has shown that the geometric distributed lag can be generated in any of three ways. Basically, the assumption about how the dis-

[6] Given the lag in the dispersement of final payments, it would seem appropriate to include the final payments variable in the acreage response function with a two-year lag. When this was done the coefficients on the final payment variables were almost always statistically insignificant. One explanation for this behavior may be that farmers anticipate the level of the final payment. In fact, it would seem likely that farmers could forecast fairly accurately the level of the final payment by comparing the Wheat Board's selling prices during the year to the level of initial payments. This hypothesis is strengthened by the fact that a simple regression of final payments on average selling prices and initial payments explains about 90% of the variation in final payments for all three crops.

tributed lag is generated affects the form of the error term in the equation estimated. In practice, how the geometric distributed lag is generated is unknown, and it may be wise to correct for serial correlation to preserve the consistency of the parameter estimates.

Empirical Results

Equations were estimated using three estimation procedures: (*a*) ordinary least squares, (*b*) ordinary least squares with the Hildreth-Lu correction for serial correlation, and (*c*) a seemingly unrelated regression procedure (Kmenta, pp. 517–28). Without exception the parameter estimates obtained from the three estimation procedures were nearly the same. Consequently, only the ordinary least squares results are reported in this paper.[7]

The acreage response functions presented in table 1 are linear in actual values and estimated using crop year data from 1949–50 through 1974–75. Student t-values are given in parentheses below each coefficient and the coefficient of determination adjusted for degrees of freedom ($\bar{R}^2$) and Durbin's h-statistic are reported.[8] Short-run and long-run elasticities calculated at mean values are given below each equation.

Wheat

Equations (3) and (6) present the results of estimating the acreage response for wheat (table 1). All of the variables in equations (3) and (6) have the expected signs and large t-ratios. The short-run elasticity of wheat acreage with respect to the initial payment for wheat (IP_w^{t-1}) is 0.53, while the cross elasticity with respect to the initial payment for barley is −0.69. The short-run acreage response with respect to changes in the final payment on wheat (FP_w^{t-1}) is 0.08 and −0.05 with respect to the final payment on barley (FP_b^{t-1}). The statistically significant coefficients on the final payment variables confirm the hypothesis that final payments have an effect on wheat acreage. The small elasticity estimates on the final payment variables are somewhat misleading in that it is not uncommon for the final payment to vary by 50% from one year to the next. The long-run elasticities in the model are approximately twice as large as the short-run elasticities.

The Canadian Wheat Board in addition to setting prices also controls the marketing of wheat through the use of marketing quotas. In some years quotas have been "open" so farmers could deliver as much grain to the Board as they want, while in other years marketing quotas have been quite restrictive and have forced Prairie farmers to store or feed the grain in excess of their quota. The variable (Z_1^{t-1}) is used as a proxy for the restrictiveness of marketing quotas and is calculated as marketings of wheat to the Board divided by production plus on-farm carry-in during crop year $t-1$. This variable ranged in value from 40% to 80% during the 1949–50 to 1973–74 crop years. A high value indicates that farmers have been able to market grain freely during the past year, while small values indicate that marketing quotas have been restrictive. Consequently, the expected relationship between Z_1^{t-1} and wheat acreage is positive, and this relationship is confirmed by the estimated short-run elasticity of 0.24.

The variable (D_{70}) is a 0-1 dummy variable equal to 1 in 1970–71 and 0 for all other years. This variable is included to account for the Lower Inventories for Tomorrow (LIFT) Program when farmers were paid not to produce wheat. The coefficient on the D_{70} variable indicates that wheat acreage was 12.09 million acres smaller in 1970–71 than it would have been in the absence of the program.[9] Neither livestock prices nor the yield of wheat relative to either barley or oats appeared to play a role in wheat acreage response, and these variables were eliminated in the final wheat response specification.

Equation (6) indicates the effect of combining the initial and final payments into single measure of price on the estimated acreage response function. The estimated direct price elasticity (0.35) from equation (6) is somewhat smaller than the elasticity with respect to the initial payment in equation (3). It is also smaller than any of the wheat price elasticities estimated by Schmitz and below the range of elasticities selected as representative by Missiaen and Coffing (p. 82).

The strong cross-price elasticities of wheat acreage with respect to both barley initial and final payment variables in equation (3) and barley price in equation (6) are contrary to the results of Schmitz, Missiaen and Coffing, and Capel in which they had difficulty in identifying strong substitute relationships.

Barley

The acreage response of barley is assumed to be a function of lagged initial and final payments on barley (IP_b^{t-1}, FP_b^{t-1}) and wheat (IP_w^{t-1}, FP_w^{t-1}) as well as livestock prices (PL^{t-1}) and the restrictiveness of wheat marketings (Z_1^{t-1}).[10] All of the vari-

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[7] The author will furnish the regression results for the Hildreth-Lu and seemingly unrelated estimation procedures on request.

[8] Durbin's h-statistic is used to test for serial correlation in equations that include a lagged dependent variable.

[9] There has been some discussion in the literature on the effect of the LIFT program on the acreage planted to wheat in 1970–71. Equation (3) indicates 12.09 million acres less wheat was planted in 1970–71 than would have been planted without the program. This is somewhat more than the estimate of 9.95 million acres made by Sahi and Craddock.

[10] Marketing quotas were also applied to barley, but this vari-

ables in equations (4) and (7) have the expected signs and large t-ratios.

The estimated direct- and cross-price elasticities of barley acreage response with respect to initial payments are quite elastic and approximately ten times larger than the elasticities with respect to final payments. When the two payments are combined into one measure of price as in equation (7), the estimated price elasticities are considerably more inelastic than indicated by the elasticities with respect to initial payments. The direct-price elasticity of 0.70 from equation (7) is similar to Missiaen and Coffing's upper estimate of 0.66.

Livestock prices have played an important role in determining the acreage of barley. Equation (4) indicates a 1% increase in the index of livestock prices will result in a 1.08% increase in barley acreage. Marketing restrictions on wheat also tend to influence the acreage of barley as indicated by the elasticity with respect to Z_1^{t-1} of -0.57.

Serial correlation is not a problem in either equation (4) or (7) as indicated by Durbin's h-statistic. In terms of goodness of fit, both equations (4) and (7) explain about 80% of the variation in the acreage planted to barley.

Oats

The acreage response estimates for oats are similar to those obtained for barley with the following exception. In comparing equations (5) and (8), the direct- and cross-price elasticities, with respect to initial payments, from equation (5) are nearly the same as those in equation (8) in which a single price term is used. This differs from the results for barley, where the response with respect to initial payments was much greater than with respect to total price.

The elasticities for oats acreage with respect to the initial payments on wheat and oats are of the same magnitude as in the wheat acreage response function but much less elastic than for barley. The final payments on wheat and oats have estimated short-run elasticities of 0.10 and -0.09, respectively. The estimated direct-price elasticity from equation (8) of 0.62 is much larger than the estimate of Missiaen and Coffing of 0.29.

Variable Z_2^{t-1} is the yield of wheat divided by the yield of oats lagged one year. The negative sign indicates that when wheat yields increase relative to oat yields the acreage of oats declines.

The coefficient of determination is quite low in both equations (5) and (8). Neither the restrictiveness of wheat marketing quotas nor a similar variable for oats improved the fit of the equation. Likewise, the variables, lagged livestock prices, and the number of milk cows on Prairie farms failed to improve the fit. Including a time trend in the oats equation improved the fit of the function slightly but only at the expense of decreasing the statistical significance of the lagged dependent variable. Obviously, some factor important in decreasing the acreage of oats has been omitted from the acreage response function, but this study can offer little guidance as to what it might be. Serial correlation is more of a problem in the oats functions than for wheat or barley, although when a correlation for serial correlation was made, the parameter estimates in equations (5) and (8) were affected only marginally.

Policy Implications

The initial payment variables included in the above equations can be considered policy variables in the sense they are specified within limits by the Canadian Wheat Board. As such they can be adjusted in order to guide farmers in their planting decisions towards some target acreage. The target acreages can be determined after careful consideration of the overall effects of different crop production levels on price and supply stability in both the grains and livestock sectors. Even so, production targets will not always be met even if acreage targets are. Separating the variance of total production into that accounted for by yield and acreage changes indicates that approximately 37% of the output variation in wheat is due to acreage changes while 43% and 45% of the variation in barley and oats output is due to changes in acreage (Burt and Finley, Goldberger). This analysis implies that considerable output variation around the target level would still exist even if actual acreage equaled the desired level.

To illustrate how initial payments could be set to achieve acreage targets, assume that in the spring of 1973, 26 million acres of wheat, 12.5 million acres of barley, and 6 million acres of oats were established as target acreages for crop year 1974–75. (These are the acreage levels indicated as desired in the spring of 1975 [Canadian Livestock Feed Board].) The question is how would initial plus adjustment payments in crop year 1973–74 have to be modified in order to achieve the stated acreage objectives for crop year 1974–75. This can be determined by using equations (3), (4), and (5) with the desired acreage of each crop replacing A_w^t, A_b^t, and A_o^t. Using equation (3) as an example and substituting 26.0 for A_w^t gives equation (9):

$$(9)\quad 26.0 = 10.25 + 7.98\, IP_w^{t-1} - 16.00\, IP_b^{t-1} + 6.89\, FP_w^{t-1} - 6.05\, FP_b^{t-1} + 9.37\, Z_1^{t-1} + 0.48\, A_w^{t-1}.$$

Inserting the relevant values for the nonpolicy predetermined variables and solving for IP_w^{t-1} in terms of IP_b^{t-1} gives equation (10):

$$(10)\quad IP_w^{t-1} = -0.41 + 2.0\, IP_o^{t-1}.$$

Following a similar procedure, starting with equations (4) and (5) and solving for IP_b^{t-1} and IP_o^{t-1}

able was found to be statistically insignificant in explaining barley acreage.

results in equations (12) and (13), giving a three-equation model containing three unknowns $—IP_w^{t-1}$, IP_b^{t-1}, and IP_o^{t-1}:

$$(11) \qquad IP_b^{t-1} = -0.31 + 0.72\, IP_w^{t-1},$$

and

$$(12) \qquad IP_o^{t-1} = -0.01 + 0.34\, IP_w^{t-1}.$$

Equations (10), (11), and (12) indicate the initial plus adjustment payment level that needs to be paid in the spring of 1973–74 to bring forth the acreage desired for crop year 1974–75. The actual mechanism would most likely involve making an adjustment payment in the spring of 1973–74 equal to the difference between the initial payment announced at the start of 1973–74 and the level of payment necessary to bring forth the desired acreage level for crop year 1974–75.[11]

Table 2 presents the actual acreage of wheat, barley, and oats in 1974–75, the acreage predicted by the model, the actual initial payments, the target acreage, and the initial payments necessary to achieve the target acreages. The results of the analysis are very surprising in that the desired acreage of all three crops was greater than actually harvested and yet the initial payments necessary to bring forth this additional acreage are all lower than actually paid. The direct- and cross-price elasticities for wheat and barley with respect to initial payments explain this phenomena. The cross-price elasticity of wheat acreage with respect to the initial payment on barley is approximately one-third larger than the elasticity with respect to the initial payment on wheat. Similarly, in the barley acreage response, the cross-price elasticity with respect to wheat acreage is about 10% greater than the direct-price elasticity. Consequently, because of the large cross-price effects, decreasing the initial price on both wheat and barley will cause the acreage of both to be increased. After determining the level of payment for wheat, all that remains is to lower the initial payment on oats until the desired level of oats acreage is achieved.

Of course, even if the above rules are followed in setting initial payment, the actual level of acreage in any year is not likely to equal the desired level. Variable weather and exogenous factors accounted for by the error term in the equations will lead to discrepancies between actual and planned acreages. Nevertheless, the acreage response functions can be used as a guide for policy makers in setting initial payment levels. Even if the policy maker disagrees with the elasticity estimates in the above equations, he can substitute his own estimates and observe the effect on the outcome.

It should be pointed out that the decision on initial plus adjustment payments this year will also affect the determination of payment levels next year. A relatively high initial payment this year implies a small final payment entering next year's supply equation, thus requiring an adjustment in the initial plus adjustment payment next year, assuming equal selling prices in each year, to maintain acreage at the previous level.

[11] Since 1971 initial payment levels for the following crop year have been announced in advance of planting in the spring. Therefore, it could be argued that since 1971 this is the price farmers use in making their planting decisions. In this analysis it was felt that the use of adjustment payments causes enough uncertainty that farmers are more likely to use actual payment levels in the spring than initial payments announced for the next crop year in their decision making.

Table 2. An Example of the Initial Payment Levels Required to Achieve Acreage Targets

	1974–75 Acreage (million acres)		
	Wheat	Barley	Oats
Actual	22.9	10.9	4.8
Predicted by model	23.1	10.9	4.8
Target	26.0	12.5	6.0
	1973–74 Initial Plus Adjustment Payments ($/bu.)		
Actual	3.75	2.25	1.10
Target	2.45	1.46	0.82

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Voluntary Rural Savings Capacities in Taiwan, 1960–70

Marcia L. Ong, Dale W Adams, and I. J. Singh

A large amount of attention has been given to mobilizing capital in and from rural areas of low income countries. In most cases, involuntary techniques such as taxes, price manipulation, forced labor, and expropriation of products have been used to do this. Rarely have policy makers considered voluntary techniques for stimulating rural savings. In part, this is due to the stereotype widely applied to rural savings behavior. This stereotype depicts rural households as having low incomes and very high consumption propensities. The lack of adequate household data on income, consumption, and savings has discouraged research that might test these assumptions (Mikesell and Zinzer).

In the following, we provide information on rural household savings and some of its determinants in Taiwan during the 1960s. Taiwan is one of the few countries that has systematically collected farm-household data for a number of years that are rich enough in detail to allow such analysis. In addition, the agricultural sector in Taiwan has experienced rapid economic and social development over the past three decades. Overall, agricultural output has increased at a rate in excess of 5% per year since the early 1950s, while the value of agricultural exports has more than tripled. The benefits from this rapid growth have been relatively equitably spread (Oshima). Furthermore, Taiwan is one of only a handful of countries that has aggressively promoted mobilization of voluntary savings in rural areas. We will argue later that these positive policies toward voluntary rural savings, rather than frugal cultural characteristics, make the Taiwan experience almost unique with regard to rural savings mobilization.

Data Used

The household data used in this study came from a farm record-keeping project. In 1953, ten agricultural vocational schools began helping a number of rural households to maintain records of their economic activities. The responsibility for the program was transferred to the local Farmers' Associations in 1960, and the Provincial Department of Agriculture and Forestry began close supervision of data collection and tabulation. Participating households were mainly located in the three major rice regions from 1960 through 1963. As can be noted in table 1, the number of participating households was more than doubled in 1964 to 535 as the project was expanded to the five additional agricultural regions on the island. From 1965 to 1970, 400 to 500 rural families kept household records each year. Many of the participants remained in the project for more than one year.

The data collected by this project are very reliable. Households voluntarily record their economic activities daily, and supervisors carefully check and aggregate this information on a regular basis. A number of consistency checks on the data showed it to be very complete and dependable. The data are more complete and reliable than information collected by most cross-sectional household surveys. Household members have a difficult time recalling for surveys small, fragmented consumption decisions that cover extended periods of time. Most households also underreport income in surveys.

As might be expected, households that voluntarily participate in record-keeping projects are not completely representative of the population. A comparison of the households in the record-keeping project and households included in a representative, island-wide rural sample survey in 1962 and 1967 show some important differences (JCRR). In 1962, for example, record-keeping households owned an average of 1.3 hectares of farm land, while the sample survey households owned 1.12 hectares. In 1967, the record-keeping households owned an average of 1.39 hectares, while survey households had only 1.08 hectares. Record-keeping households owned, therefore, 20% to 30% more farm land than the average farm family. At the same time, there was little difference in average family size between the two groups. In 1962, record-keeping households had average incomes and consumption expenditures that were 60% and 47%, respectively, above the average survey household. In 1967, there was much less difference between the two groups. Record-keeping household incomes were 29% greater and consumption expenditures only 2% greater than survey household figures. As was suggested earlier, it is likely that the survey data underreported household incomes. The

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Table 1. Number of Households and Average and Marginal Propensities to Save, Taiwan Farm Record-Keeping Data, 1960–70

Year	Number of Households	*YBAR/N*[a]	*CBAR/N*[a]	APS[b]	Estimated Coefficients[c] a_0	a_1	R^2	MPS[d]
		----- 1970 NT$ -----						
1960	95	4,609	3,784	0.18	739.3	0.623 (13.9)[e]	0.68	0.38
1961	207	5,358	4,364	0.19	1,219.8	0.542 (21.0)	0.68	0.46
1962	233	5,731	4,504	0.21	1,355.7	0.488 (18.8)	0.62	0.51
1963	227	5,750	4,421	0.23	1,675.6	0.432 (16.2)	0.49	0.57
1964	535	5,691	4,346	0.24	1,364.7	0.496 (30.6)	0.64	0.50
1965	501	6,151	4,702	0.24	1,013.6	0.580 (29.3)	0.63	0.42
1966	430	6,711	4,840	0.28	2,426.0	0.315 (17.4)	0.42	0.69
1967	402	6,784	5,136	0.24	1,372.6	0.541 (22.0)	0.55	0.46
1968	416	7,122	5,140	0.28	1,850.9	0.457 (23.6)	0.57	0.54
1969	411	6,388	5,645	0.12	1,433.4	0.649 (20.9)	0.52	0.35
1970	404	6,778	5,409	0.20	1,813.0	0.531 (21.1)	0.53	0.47

Source: Ong.
[a] *YBAR* equals average net farm family income; *CBAR* equals average household expenditures, and *N* equals number of individuals residing in the household during the year. Current New Taiwan dollar (NT$) figures were converted to 1970 prices using general index of prices received by farmers published by the Bureau of Accounting and Statistics, Provincial Government of Taiwan: 1960 = 81.0, 1965 = 89.2, and 1970 = 100.0.
[b] APS is the average propensities to save calculated at mean farm family income and household expenditure levels for each year (1 − *CBAR/YBAR*).
[c] These are estimates of the linear per capita consumption function $(C/N)i = a_0 + a_1\ (Y/N)i$.
[d] MPS is the marginal propensity to save calculated at the arithmetic mean income and expenditure levels for each year $(1 - a_1)$.
[e] Figures in brackets are t-values for the slope coefficients. All coefficients are significant at the 1% level.

real differences between the incomes of the two groups is probably less than the above percentages indicate. Because of the relatively homogeneous nature of farms in Taiwan, the record-keeping households come closer to representing the entire population than would similar accounts in other higher income countries. Nevertheless, the savings capacities of the record-keeping households reported in the following may overstate somewhat the savings capacities of average rural households in Taiwan.

Methodology

Savings capacities are estimated in this study through income consumption relationships. Savings are defined as total net household income (Y) minus total household consumption (C). Consumption includes the value of all purchased goods for the household as well as products produced and consumed on the farm. This includes costs for household operations, education, and health and purchases of consumer durables. (See paper by Adams, Canh, and Chin for further detail on these items.) To the extent that education expenses and consumer durable purchases contain savings components, the following estimates of household savings are underestimated.

To remove the effect of the size of the family, income and consumption information was converted to per capita figures by dividing through by the number of people living in the household (N). Initially, four functional forms were used in the analysis: linear, quadratic, semi-log, and double log. As Ong points out, results from the linear and double log forms consistently gave the highest F-ratios and smallest standard errors. Since both of these functional forms gave roughly the same statistical results, the coefficients for the linear form are used in the following discussion. The linear form used was

$$(C/N)_i = a_0 + a_1\ (Y/N)_i + u_i,$$

where u = the residual term. This per capita function was estimated using ordinary least squares. Cross-sectional data for eleven consecutive years (i), 1960–70, were analyzed.

Propensities to Save

Yearly per capita income and consumption figures for the record-keeping households are shown in table 1. It can be noted that average per capita income of the record-keeping households increased in real terms by almost 50% over the eleven-year period, a compounded rate of almost 4% per year. Household expenditures also increased substantially over the period, though at a slightly slower rate than did incomes. This resulted in a gradual increase in the average propensity to save (APS) over the 1960–68 period. The very high APS's of the record-keeping households during the period under study are impressive. In the early 1960s, households were saving roughly one-fifth of their incomes. In the 1964–68 period, rates of savings increased to roughly one-quarter of total income. The sharp down turn of APS in 1969 was due in part to very adverse weather that seriously affected agricultural production and incomes. Part of the decrease in APS in 1969 and 1970, however, may also have been caused by the large increase in availability of very attractive consumer goods that began entering rural markets in the mid-1960s (Freedman). The decline in the average saving rates may also have been due to lower rates of return to on-farm investments in the late 1960s, which may have further discouraged household savings.

Information on the marginal savings behavior is also given in table 1. Estimates of the short-run marginal propensities to save (MPS) throughout the 1960s were fairly high, ranging from one-third to two-thirds of marginal income. The substantial variability in MPS from year-to-year plus the overestimation bias of short-run estimates limit the ability to specify savings behavior from cross-sectional data. Despite this, marginal savings appear to have been quite high.

Other Determinants of Savings Capacities

Studies by Mizoguchi, Noda, and others have suggested that savings performance among households may vary considerably depending upon farm size (often used as a proxy for income) and upon source of income. To test this, the Taiwan households were grouped into three farm-size categories: less than 1 hectare, 1 to 2 hectares, and more than 2 hectares. A second classification of the households was based on the ratio of income derived from on-farm agricultural activities to total household income. Average and marginal propensities to save among these different subgroups for the period 1960–70 are presented in table 2.

A review of the average propensities to save by farm size groups shows that APS's almost always increase with farm size. In part, this reflects the favorable impact on savings of higher incomes,

Table 2. Average and Marginal Propensities to Save by Farm Size Groups and Income Source Groups for Record-Keeping Households in Taiwan, 1960–70

	Years										
Groups	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
					Average Propensities to Save[a]						
By farm size (ha.)											
0–1[b]	0.15	0.14	0.16	0.21	0.17	0.18	0.19	0.19	0.23	0.07	0.13
1.01–2	0.16	0.21	0.22	0.21	0.25	0.26	0.28	0.25	0.27	0.10	0.23
2+	0.28	0.19	0.26	0.30	0.32	0.30	0.39	0.29	0.34	0.19	0.24
By ratio of farm income to total household income											
0–0.7	0.09	0.18	0.24	0.14	0.16	0.22	0.22	0.30	0.23	0.07	0.14
0.7+	0.19	0.19	0.21	0.25	0.26	0.24	0.30	0.26	0.29	0.15	0.24
					Marginal Propensities to Save[c]						
By farm size (ha.)											
0–1	0.60	0.42	0.49	0.68	0.40	0.46	0.50	0.46	0.44	0.48	0.34
1.01–2	0.26	0.45	0.54	0.49	0.43	0.40	0.68	0.45	0.48	0.40	0.56
2+	0.78	0.51	0.50	0.50	0.61	0.40	0.77	0.46	0.63	0.21	0.46
By ratio of farm income to total household income											
0–0.7	0.32	0.53	0.60	0.34	0.28	0.36	0.60	0.27	0.41	0.15	0.26
0.7+	0.39	0.45	0.49	0.59	0.56	0.45	0.70	0.56	0.58	0.52	0.56

Source: Ong.

[a] Average propensity to save equals 1 − household expenditures/household income.

[b] One hectare (ha.) equals 2.47 acres.

[c] Marginal propensity to save is calculated at the arithmetic mean income and expenditure levels for each year. As in table 1, results are from a linear function form.

which in turn are associated with farm size. In a separate study of the same data, Chin found a very close, positive relationship between household income levels and APS's. The generally higher APS's and MPS's among the larger farms also suggest that households with more farm land may have had more profitable on-farm investment alternatives for their savings than did smaller landowners. A further point worth noting in table 2 is the relatively high APS's and MPS's among households in the smallest farm-size groups and that the marginal savings behavior of households with small farms was not vastly different from households with larger land areas.

Also shown in table 2 is a breakdown of APS's and MPS's by income-source ratios. Households with the highest ratios received a larger part of their total income from on-farm agricultural activities than did households with low ratios. These APS's and MPS's were fairly consistent in showing better savings performance among high ratio households. These results tend to confirm Noda's findings in Japan, that households that are close to full-time farming units tend to have larger savings propensities than do those households that derive a substantial part of their income from outside their own farming operation. As with the farm-size situation, these income ratios may be associated with overall income levels of households as well as reflect profitability of on-farm investment opportunities.

The record-keeping households were also grouped by their eight regional locations and by two household-dependency ratios (Ong). Neither of these breakdowns shed additional light on savings behavior. Savings patterns in various geographic regions of Taiwan appear to be very similar. Likewise, there appears to be little difference in savings performance between high and low dependency ratio households.

Implications

As indicated before, the data used in this study tend to overstate average rural savings capacities in Taiwan. The households studied have higher than average incomes, they are progressive farmers, and the cross-sectional estimates reported here overestimate long-run MPS because of the transitory income effect. We feel this upward bias is largely offset, however, by our exclusion from savings in the study all expenditures on education and consumer durables. During the 1960s, the average record-keeping household used 10% to 15% of its total consumption in these activities (Adams, Canh, and Chin). Half or more of these expenditures could have been defined as savings with strong justification. These data, plus other indicators, reinforce the conclusion that very large voluntary savings capacities emerged in rural Taiwan during the 1960s. The large increase in financial savings in rural areas and the rapid increase in total on-farm assets are physical evidence of substantial savings capacities (Tuan). The well-documented transfer of capital out of the agricultural sector, the sharp increases in rural human capitalization, and the widespread accumulation of consumer durables in rural areas lend further weight to the argument that a surprisingly large part of the rural product in Taiwan during the 1960s was voluntarily saved.

It might be aruged that the large rural savings capacity found in Taiwan during the 1960s is a special case, that Taiwanese are somehow culturally endowed with large doses of frugality. We do not feel that household characteristics are the major explanation of Taiwan's remarkable savings performance. We also do not feel that the substantial increases in rural incomes during the 1960s make the Taiwan experience unique. Individual farm households and major agricultural regions in a number of other less developed countries also are experiencing high rates of growth in incomes. We conclude that Taiwan's savings performance is due to appropriate policies rather than unique behavioral characteristics. Household savings were strongly stimulated by two sets of incentives. The first set included price policies, new technology, marketing facilities, land-tenure adjustments, and public-investment programs that gave strong incentives for on-farm investments. The second set of savings incentives flowed to farmers through financial markets. The physical presence of savings institutions in most rural areas (postal savings, farmers' associations, and commercial banks) gave rural people the opportunity to save. These institutions provided the convenience, stability, liquidity, and security necessary to attract savings. Furthermore, Taiwanese policy makers were very agressive in using attractive interest rates on deposits to induce savings. During the 1950s and 1960s, interest rates on deposits were adjusted, sometimes monthly, to assure positive real returns to financial savers (Tuan).

The Taiwan experience during the 1960s seriously challenges the low saving capacity stereotype that has been routinely applied to rural households. We feel that using a more realistic notion of rural saving behavior in economic planning should receive a high priority in the development profession.

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The Marketed Surplus of a Subsistence Crop: Paddy Rice in Taiwan

Dennis L. Chinn

The price response of the marketed surplus of subsistence crops is a topic of major concern to agricultural planners in developing countries. Recent attempts to measure the relevant elasticities by Bardhan, Haessel, and Toquero et al. have significantly added to understanding the magnitudes involved but seem to possess potentially serious methodological limitations. First, they do not explicitly consider the "barter component" of marketed surplus. Haessel recognizes the existence of in-kind disposals but assumes them to be fixed by contractual arrangements and hence insensitive to changes in price. If the barter component is large, even a small response to a change in price may be important for policy purposes. A second limitation is the assumption that sales and on-farm consumption are strict complements, so that it is necessary to consider the price response of either marketing or consumption but not both. While this results in considerable simplification, it ignores the farmer's additional option of simply adding to (or subtracting from) existing stocks.

The present paper considers the marketed surplus of paddy rice in Taiwan, a case in which the barter component is important. For a sample of farm households in the middle rice region of Taiwan, paddy rice used to pay in-kind household and farm expenses amounted to over 60% of cash rice sales for the period 1962–72. The simple approach adopted disaggregates total marketed surplus into cash sales and barter components and also allows for separate estimation of the price and output elasticities of on-farm consumption. A further departure from previous studies is that the estimation is based on time-series data. The approach generates what appear to be quite reasonable estimates of the price and output elasticities and suggests that the numerical results of studies that ignore the barter components of marketed surplus may require qualification.

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This study was made possible by Dale Adams, who made available the data on which it is based. The data were drawn directly from the individual records of the Taiwan Farm Record-Keeping Project with the cooperation of the Joint Commission on Rural Reconstruction, Taiwan, and support from the U.S. Agency for International Development. Partial support for the author's research was provided by the same source under the auspices of the Stanford project on the political economy of rice in Asia. The helpful comments of Keith Acheson and *Journal* referees are gratefully acknowledged. Any remaining weaknesses are the responsibility of the author.

Following a brief discussion of the nature and limitations of the available data, the estimated structural equations are described, the elasticity estimates derived, and the conclusions summarized and qualified.

Data

The basic identity of the farm household rice economy is

$$(1) \quad QOUT = QSOLD + HOUSKD + FARMKD + QCONS + \Delta STOCKS.$$

Total rice output for a given year (*QOUT*) can be disposed of in several ways. It can be sold for cash in the free market (*QSOLD*), bartered for household consumption items (*HOUSKD*), used to pay in-kind farm expenses including land rents and taxes (*FARMKD*), consumed directly by the farm household (*QCONS*), or added to end-of-year stocks ($\Delta STOCKS$), the final term representing a positive or negative residual. Paddy rice not consumed on the farm or added to existing stocks is assumed to eventually find its way into market channels, so total marketed surplus (*MS*) is given by

$$(2) \quad MS = QSOLD + HOUSKD + FARMKD.$$

Most of the data used in this study are drawn from the Taiwan Farm Record-Keeping Project, which was initiated in the early 1950s and took its present form in 1960.[1] The analysis is restricted to sample households in the middle rice region for the period 1962–72. From the farm records an annual time series for the average sample household can be derived for each item in equation (1).

The figures for total paddy rice output (*QOUT*) were originally reported in quantity terms, while *QSOLD* was estimated by dividing the annual receipts from rice sales by the average annual free market paddy rice price (*PRICE*).[2] The items re-

[1] Summary data from the Taiwan Farm Record-Keeping Project as published each year since 1960 by the Department of Agriculture and Forestry of the Provincial Government of Taiwan were not sufficiently detailed for purposes of this study. The time series used were constructed from the individual farm household records.

[2] It was not possible to derive an implicit price series from the farm-household records. The time series for *PRICE* is the annual average free market price of paddy rice as reported in Chen, Hsu, and Mao (p. 23).

corded in the farm records include in-kind household expenditures, in-kind farm expenditures, and total staple food consumption in value terms for each year 1962–72. Since rice was the primary medium for in-kind transactions (and the primary staple food crop), dividing by the average paddy rice price for each year yields estimates of total direct household use of paddy rice, paddy rice used to pay in-kind farm expenses (*FARMKD*), and direct farm household consumption of paddy rice (*QCONS*) in quantity terms. Subtracting the last from the first yields a residual estimate of paddy rice bartered for household items excluding direct consumption (*HOUSKD*).

Other data used in this paper include total farm household income from all sources (*TOTINC*), the average paddy rice yield (*AVGYLD*), the total number of family members (*TOTFAM*), the total farm land owned by the household (*TOTFLAND*), and the fertilizer-rice barter ratio (*FERTRICE*).[3]

Table 1 presents some important trends for the average sample farm household for the period 1962–72 broken into three subperiods. The average size of holding (*TOTFLAND*) increased somewhat as did total rice production (*QOUT*). The share of total output sold for cash (*QSOLD*) increased from 0.44 to 0.55, while the proportion consumed by the farm household (*QCONS*) fell only slightly from 0.28 to 0.25. For each subperiod the sum of the barter components (*HOUSKD* + *FARMKD*) accounts for about 30% of total output. The term $\Delta STOCKS$ was estimated as a residual, and the negative entry for each period may in part reflect some in-kind consumption of staple crops other than paddy rice.[4] Over the period total farm household income (*TOTINC*) doubled, while the proportion of total income attributable to rice declined from 0.46 to 0.29, reflecting both the increase in part-time farming and to a lesser extent the shift in the crop mix over time.[5]

The strengths of the farm household record-keeping data are the number of years for which the records are available that makes time-series analysis possible and the extraordinary amount of detail that makes it possible to disaggregate total marketed surplus of paddy rice. As always, however, there is no "free lunch," and these strengths are balanced by potentially serious weaknesses. First, for each year the sample size is quite small. An average of seventy-one households in the middle rice region participated in the record-keeping project during 1962–72, the minimum being forty-nine in 1967 and the maximum eighty-one in 1963. Second, and most importantly, the sample households were selected by the agricultural cooperative associations, and the extent to which they are representative of farm households in the middle rice region as a whole cannot be determined. The obvious danger is that spurious correlation might be introduced simply through the choice of sample households. In any case there is nothing that can be done about either the small sample size or the apparent lack of randomness in the sampling process. While it is the author's belief that the potential gain in insight far outweighs the costs of potential errors, the difficulties of interpreting the average sample farm household for each year as one observation in a time series should be kept in mind.

Estimated Equations

The approach of this study is to fit a simple model of farm household behavior to the time-series data described above and to derive estimates of price and output elasticities for the components of total marketed surplus and on-farm consumption. The model consists of five equations, one for each element of equation (1), except for the residual term $\Delta STOCKS$. All variables are expressed in natural logarithms, the equations are estimated by ordinary

[3] During the period under consideration, chemical fertilizer supplies were distributed by the government monopoly in exchange for paddy rice. The variable *FERTRICE* is the barter ratio measured in kilograms of paddy rice per kilogram of fertilizer. See Lee for a brief description of the system. The time series for *FERTRICE* was taken from Chen, Hsu, and Mao (appendix, table 9).

[4] If in-kind staple food consumption includes commodities other than paddy rice, then the estimation procedure adopted here will overstate *QCONS* and impart a negative bias to $\Delta STOCKS$. The residual term may also include a statistical discrepancy because the price series is an average annual price series and is from an independent source and hence may not be identical to the actual prices received by the sample farm households.

[5] The proportion of total farm-household income from farm sources declined from 0.85 for 1962–65 to 0.64 for 1970–72, while rice receipts as a proportion of total farm receipts declined from 0.54 to 0.46.

Table 1. Selected Trends for the Average Sample Household, 1962–72

Time Period	*TOTFLAND*[a] (chia)	*QOUT* (kgs.)	Proportions of *QOUT*					*TOTINC* (U.S. $)	Proportion of *TOTINC* from Rice[b]
			QSOLD	*HOUSKD*	*FARMKD*	*QCONS*	$\Delta STOCKS$		
1962–65	1.07	7,034	0.44	0.12	0.23	0.28	−0.07	880	0.46
1966–69	1.19	7,656	0.48	0.09	0.22	0.24	−0.03	1,111	0.43
1970–72	1.31	8,177	0.55	0.12	0.16	0.25	−0.08	1,717	0.29

[a] 1 chia = 0.97 ha.
[b] The farm-record data do not allow allocation of costs between individual crops or other farm activities. The contribution of rice to income from farming is assumed to be equal to the ratio of total rice receipts to total farm receipts. This ratio times the share of income from farming in total income then represents the share of *TOTINC* from rice.

least squares, and the t-ratios are shown in parentheses:[6]

$$(3) \quad QOUT = \underset{(3.148)}{0.710\, PRICE(-1)} + \underset{(24.001)}{0.941\, AVGYLD}, \quad R^2 = 0.740;$$

$$(4) \quad QSOLD = -3.400 + \underset{(1.892)}{0.677\, PRICE} + \underset{(4.090)}{1.338\, QOUT} - \underset{(0.868)}{0.632\, TOTFAM}, \quad R^2 = 0.871;$$

$$(5) \quad FARMKD = \underset{(1.402)}{0.339\, PRICE} + \underset{(17.777)}{0.744\, QOUT} + \underset{(8.722)}{0.531\, FERTRICE}, \quad R^2 = 0.926;$$

$$(6) \quad HOUSKD = 2.266 - \underset{(2.863)}{2.315\, PRICE} + \underset{(3.533)}{0.795\, TOTINC} - \underset{(0.527)}{0.308\, TOTFAM}, \quad R^2 = 0.588;$$

and

$$(7) \quad QCONS = 4.171 - \underset{(1.168)}{0.349\, PRICE} + \underset{(1.132)}{0.309\, QOUT} + \underset{(0.885)}{0.538\, TOTFAM}, \quad R^2 = 0.404.$$

In principle, a change in price can affect output through an induced increase in yield or acreage or both. In the sample data the crude correlation coefficient of *AVGYLD* with the price series lagged one year (*PRICE*(−1)) was −0.09, while that for land devoted to paddy production was 0.63, suggesting that any positive effect of lagged price on output over time came from the acreage side. Equation (3) attempts to capture that effect. The constant term had a low t-ratio and the equation was reestimated without it. The coefficient of *PRICE*(−1) implies that (holding *AVGYLD* constant) a 1% increase in price would correspond to a 0.7% increase in paddy rice output in the following year.

Equations (4) and (7) relate *QSOLD* and *QCONS* to the average free market price in the current year (*PRICE*), total paddy rice output (*QOUT*), and the total number of family members (*TOTFAM*). In both equations the *TOTFAM* coefficient has a small t-ratio, but the coefficient is of expected sign. Equation (7) is a bit suspect in terms of statistical fit, but the coefficients of *PRICE* and *QOUT* have the expected signs and do appear to be of reasonable magnitudes.[7] Attempts to relate *HOUSKD* to the same three variables were unsatisfactory, so *TOTINC* was substituted for *QOUT* and the result is shown as equation (6).[8] Paddy rice used to pay farm expenses (*FARMKD*) is quite adequately explained by *PRICE, QOUT,* and the fertilizer-rice barter ratio (*FERTRICE*), the last term being included to reflect the importance of the barter of paddy rice for fertilizer as a component of *FARMKD*. As in equation (3), the constant term had a low t-ratio and was eliminated. Thus, with minor problems the set of log-linear equations (3) through (7) seems to be a satisfactory representation of the farm household rice economy.

Estimated Elasticities

This section describes the construction of table 2. Since the estimated equations are log-linear, the coefficients represent constant elasticities. The coefficients of *PRICE* in equations (4), (5), and (7) represent short-run (output held constant) price elasticities of *QSOLD, FARMKD,* and *QCONS,*

[6] The decision to impose the constant elasticity functional form on each equation reflects our interest in the distinction between long-run and short-run price elasticities (with and without the induced effect on output) rather than variations in the elasticities over the ranges of the explanatory variables. The gain in analytical simplicity seems well worth the potential loss in statistical goodness of fit.

[7] Due to the poor statistical fit of equation (7), an alternative equation for *QCONS* with *TOTINC* in place of *QOUT* was estimated:

$$QCONS = 4.443 - \underset{(3.100)}{1.375\, PRICE} + \underset{(2.818)}{0.348\, TOTINC} + \underset{(2.084)}{0.667\, TOTFAM}, \quad R^2 = 0.648.$$

This equation gives a better statistical fit but yields what seems to be an overly high estimate of the long-run price elasticity of *QCONS*, −1.15.

[8] Equation (6) was fit to data for the years 1960–72 since each of the variables involved was available for 1960 and 1961. The other equations were estimated for the period 1962–72.

Table 2. Estimated Elasticities

	Short-Run Price Elasticity[a] (1)	Long-Run Price Elasticity[b] (2)	Output Elasticity[c] (3)
QOUT	—	0.71	—
MS	0.22	0.97	1.06
QSOLD (0.62)	0.68	1.63	1.34
FARMKD (0.24)	0.34	0.87	0.78
HOUSKD (0.14)	−2.01	−1.80	0.30
QCONS	−0.35	−0.13	0.31

[a] The price elasticity in the absence of any change in output.
[b] The price elasticity including the induced change in output.
[c] The induced response to an exogenous change in output.

respectively. For *HOUSKD*, equation (6), there is an additional current price effect through the *TOT-INC* term. Earnings from rice increase in proportion to current price, and since for the period 1962–72 rice accounted for about 38% of total farm household income, the short-run price elasticity of *HOUSKD* is $-2.315 + (0.38)(0.795) = -2.01$. The coefficients of *QOUT* in equations (4), (5), and (7) represent short-run (price held constant) output elasticities. The short-run output elasticity of *HOUSKD* is $(0.38)(0.795) = 0.30$. The short-run price and output elasticities of total marketed surplus (*MS*) are calculated as weighted sums of the respective elasticities of the component parts *QSOLD*, *HOUSKD*, and *FARMKD*. The weights (shown in parentheses in the table) are the shares of *MS* for 1962–72. The short-run price and output elasticities are given as columns 1 and 3, respectively, of table 2.

The long-run price elasticities of *QSOLD*, *FARMKD*, and *QCONS* shown in column 2 were calculated by substituting equation (3) into equations (4), (5), and (7) and summing the coefficients of the current and lagged price terms. The coefficient of *PRICE*(−1) in the reduced form of equation (6) is $(0.38)(0.71)(0.795) = 0.21$. Adding this to the short-run price elasticity yields a long-run elasticity of −1.80. The long-run price elasticity of total marketed surplus was calculated in the same way as the short-run price and output elasticities.

Conclusions and Qualifications

The following conclusions can be drawn from the numerical results.

(*a*) The short-run price elasticity of total marketed surplus is positive, while that of on-farm consumption is negative, suggesting that for a given level of paddy rice output, an increase in the market price would induce farmers to market a higher proportion of that output. Farm households in Taiwan respond to changes in price both as sellers and as consumers.

(*b*) In the long run, including the induced effect on output, a 1% rise in price would result in a 0.97% increase in total marketed surplus. On-farm consumption would decline but only by 0.13%. Hence, price policies designed to stimulate output would also stimulate the transfer of staple food output from the peasant farming sector to the urban sector.

(*c*) An exogenous 1% increase in output, say, through an increase in average yield due to the introduction of new high yielding rice varieties, would result in an increase in total marketed surplus of 1.06% but would also result in a 0.31% increase in on-farm consumption of paddy rice.

(*d*) There is significant variation between the elasticities of the components of total marketed surplus. The long-run price elasticity of *QSOLD* is quite high at 1.63, that of *FARMKD* is almost half that at 0.87, while that of *HOUSKD* is negative and quite large at −1.80. The output elasticities of the three items are all positive but differ significantly in magnitude. Hence, the disaggregated approach seems justified. The output and price elasticities of total marketed surplus are substantially lower than the corresponding elasticities of *QSOLD*. This suggests that neglecting the barter components of total marketed surplus may result in serious overestimation of the price and output responses.

Some qualifications of these conclusions should be noted. The absolute magnitudes of the long-run price elasticities depend on the lagged response of output to price. The imposed log-linearity of the equations precluded more detailed specification of the lag structure of the production response, and it is conceivable that the estimated price response is inaccurate.[9] However, given the small number of observations, itself a severe limitation, it seems unlikely that a more detailed lag distribution would yield much better results. A perhaps more serious qualification has to do with the data problems mentioned previously. If the composition of the sample households changes systematically from year to year there may be spurious correlations between some of the variables and the price series. There is no reason to assume that the sample is not representative, and in any case there is simply not much that can be done about it. Again, it is the author's belief that the benefits of using the data for time-series analysis far outweigh the costs of potential errors.

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[9] In spite of the simplicity of equation (3), the estimate of the price elasticity of paddy rice output (0.71) is only slightly higher than other estimates. For example, estimates of long-run price elasticities of rice acreage for regions of the Philippines and the Punjab cited by Krishna range from 0.15 to 0.62, while for prewar Japan Hayami and Ruttan estimate the elasticity to be between 0.4 and 0.6. The consequences of overestimation of the price elasticity of output in the present context would be a too high estimate of the long-run price elasticity of total marketed surplus and a too low (in absolute value) estimate of the price elasticity of on-farm consumption.

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The Political Economy of Rural Development in Latin America: An Interpretation: Comment

W. Whitney Hicks

In an article in this *Journal*, Alain de Janvry argues that increased poverty among marginal farmers (*minifudistas*) in Latin America leads to an increase in family size and ". . . poverty thus leads to more poverty" (p. 495). This implies not only that fertility is high in low income rural areas but that as income decreases fertility increases. De Janvry feels that the ". . . ecological and demographic contradictions in the subsistence sector . . . (are) . . . an integral part of the dynamics of growth in peripheral economies of the world capitalist system . . . (and that his theory that includes these ecological and demographic contradictions in the subsistence sector) permits identification of the variables that affect rural poverty and understanding of the political economy of alternative strategies aimed at alleviating it" (pp. 495–96).

I will argue on both theoretical and empirical grounds that poverty and the mining of land in rural areas is associated with lower rather than higher fertility and against the existence of ecological and demographic contradictions that lead from rural poverty to increasing family size to even greater poverty.

In the case where children are producer goods (rather than consumer goods (Becker)), de Janvry maintains that "the pressure of poverty in the *minifundio* implies the need to search for additional productive resources. Strict individual economic rationality in the subsistence sector will often lead to mining the land and increasing family size in order to face poverty, and poverty thus leads to more poverty" (p. 495). In contrast to de Janvry's assertion about the consequences of individual economic rationality on fertility, neoclassical economic theory posits that the determinants of fertility in rural areas are the factors that influence the net returns to rural households from additional units of family labor. If, for example, the marginal cost of children is constant and the marginal benefits depend on the available supplies of land, labor, and reproducible capital, increasing family size beyond a point will cause the marginal returns to parents to fall below the marginal cost. Land is a prerequisite for livelihood in rural areas, and when it is scarce the establishment of a household may be delayed or avoided. If the average size of holdings is small, there is an incentive to limit fertility within marriage to prevent further fragmentation of holdings and a further decline in the marginal productivity of labor. This suggests that fertility in rural areas is directly related to land availability and that as population density on the land increases fertility will decrease.

The results of two recent studies for Latin American countries provide empirical support for the above hypothesis. One is a study of the rural population in 166 microregions (which are aggregations of *municipos*) in seven states of South-Central Brazil—Paraná, Mato Grosso, Goiás, Bahia, Minas Gerais, São Paulo, and Rio Grande do Sul (Merrick). Measures of fertility (age-specific fertility rates or births per 1,000 women in five-year age groups [15–19, 20–24, . . . , 45–49] and completed fertility or the number of children ever born to women ages 45–49) from the 1970 population census and of land availability (the ratio of total agricultural land to the total area in the microregion) from the 1970 agricultural census are used to test the hypothesized relationship. Merrick states that

> "Tabular and multiple regression analysis of the data for land availability and fertility rates reveal a strong and relatively consistent tendency for fertility to decline with decreasing land availability. The regression analysis allowed us to control this relation for the effect of differential survivorship and property ownership. The influence of land on fertility was stronger in the current rates (age-specific fertility rates) than for cumulative ones (children ever born to women ages 45–49), with the effect most pronounced in the more important child-bearing cohorts between ages 20 and 34" (p. 27).

A similar study has been made for the rural areas of the thirty-one "states" of Mexico in 1970 (Hicks 1974). In this case the measure of fertility was children ever born to women ages 40–44 and the measure of land availability was arable land per farm worker. A multiple regression model that controlled for differences in female literacy, the crude death rate, and the relative size of the indigenous population showed ". . . that the land variable was positive and statistically significant at the five percent level. (These) results are consistent with the hypothesis that arable land is complementary with labor, and fertility is likely to decline in response to a decrease in arable land per agricultural worker" (Hicks 1974, p. 414).

There is some evidence that the relation between

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land availability and fertility is conditioned by the tenure arrangement. Merrick found ". . . that the land scarcity effect is weaker when property ownership is less common. However (he concluded that) more refinement of the property ownership variable is required before definite conclusions on its effect can be reached" (p. 27). A paper summarizing three studies that show differential fertility by land-tenure classes in Mexico suggests that fertility was higher on *ejidos* than on privately owned farms (Sanchez). However, none of the three studies summarized controlled for "land availability," and in each case it appears that arable land per farm worker was greater for *ejidos* than for private properties (Hicks 1967, p. 398).

Further research is needed on the interrelationships between fertility in rural areas, land availability, land tenure status, and the mechanisms by which these factors interact. Easterlin's "bequest" model for explaining fertility differences during frontier settlement in the United States is one example of such research, although this model may not be applicable to Latin America (Easterlin).

In view of de Janvry's failure to support his assertions about the relationship between poverty and fertility, the evidence in support of a direct relationship between fertility and land availability must be tentatively accepted. The "ecological and demographic contradictions" that help to drive de Janvry's model of rural development may not exist.

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The Political Economy of Rural Development in Latin America: An Interpretation: Reply

Alain de Janvry

I have argued, along with others (Mamdani), that poverty is a powerful stimulant of higher birth rates and this particularly in the context of semiproletarian subsistence agriculture. There, the conjunction of poverty and the control of some productive resources makes children an essential means of production and protection. The rural poor thus have large families because it is economically rational for them to do so. Improvement in the material conditions of life—increased control of productive resources, larger access to income-generating activities, consumption levels covering subsistence needs, greater safety of survival, and social security—diminishes this function of children and gradually transforms them into consumer goods, thus leading to a decline in birth rates and to a "demographic transition" (Oechsli and Kirk).

Hicks, like neo-Malthusians, claims the opposite: that rural poverty is associated with lower rather than higher fertility.[1] Yet, the theoretical and empirical evidence he puts forward does not support his assertion. Poverty is unacceptably reduced to land availability under *ceteris paribus* conditions. This fallacious reasoning is tantamount to claiming that the organization of production is unrelated to farm size and that land availability is the only determinant of poverty.[2]

The basic starting point from which a relationship between poverty and fertility can be established is the well-evidenced observation that, even among the most primitive, fertility decisions (desired family size) are rational and ultimately determined by economic criteria (Hawthorn). Completed family size may, however, exceed desired family size due to the crudeness of the control practices used and the uncertainties of planning under conditions of high infant mortality. Yet, this difference is a minor determinant of family size relative to the rationality of choices. Family-planning programs often have succeeded merely to induce those couples already practicing birth control to switch to more efficient, modern methods with only a minor overall affect on family size.

Clearly, the organization of production changes with farm size, and for this reason so does the productive and protective functions of children. On larger farms the marginal revenue schedule of children is shifted downward as nonfamily labor is employed, laborsaving machinery is used, the nature of the tasks performed is more complex and physically demanding, etc. Greater access to credit, information, and protective institutions in general, which is invariably associated with farm size, reduces the social security function of children. Better standards of living for the children and school attendance increase their marginal costs. As a result, larger farms tend to be associated, *mutatis mutandis*, to smaller family size.

Because of the insufficiency of land resources controlled relative to subsistence needs, the vast majority of poor rural households are semiproletarians.[3] In the resulting division of labor, the women, the young, and the old become the prime agriculturalists. Because of the primitive nature of techniques and the pressure of poverty, a highly labor-intensive production pattern is followed that allows for no idle labor and to which all but the very young and very old participate. Even the most limited improvements, such as raising a goat or a pig (animals are the saving accounts of subsistence peasants), imply the need for additional child labor. As for tenants, the more hands a family can muster, the more land a family may be able to contract from the landlords.

Use of hired labor is not a substitute for one's own children to cover labor needs simply because overexploitation of labor within the family can be so much greater and the total claim of the family on the lives of its children until adulthood prohibits existence of a labor market for rural children. As Mamdani observes,

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[1] For example, Garret Hardin, who claims that "more food means more babies."

[2] For empirical support, Hicks refers to his study of Mexican rural fertility. Both the data used and the variable specified are highly inadequate; the data are aggregates for the states of Mexico, while we are dealing here with individual fertility behavior! The variable used for land availability is arable land per worker in each state without accounting for the distribution of the land and for land quality. In states of high land fertility, rural population density is high, and large commercial farms and also a large number of poor subsistence farms providing labor to the commercial sector are found. Under the typical dual Latin American land-tenure system, a high level of land per worker can just as well mean that a majority of the rural population lives under extreme poverty.

[3] According to the Inter-American Committee for Agricultural Development, semiproletarian rural households (subfamily farms) account for 44% of all rural households in Argentina, 61% in Chile, 72% in Colombia, 78% in Brazil, 88% in Ecuador, and 91% in Guatemala (see Barraclough).

> "Given a very small income, to have to hire even one farmhand can mean disaster. If such a farmer is merely to survive, he must rely on his family for the necessary labor power. If he is to think of any advancement, which every farmer in such a precarious situation does, he must add to his family labor force and thus augment his resources" (p. 76).

Children not only fulfill a role as production agents in subsistence agriculture but also provide protection. They provide security to parents against health hazards, disability, and old age, against unemployment, and against structural and economic changes to which the work process has to be adjusted when parents may not have the needed flexibility to do so. In some cases a large family is needed for sheer physical defense of scarce productive resources in a ferociously competitive environment ruled by the laws of survival.

As poverty increases, children will be induced to migrate away from the family at an earlier age, and as the migration age decreases procreation of more children is needed to maintain a constant stock of working children—a stock that itself has to increase with poverty. While the migrants cease to perform as production agents on the farm, they continue to insure protection; they can provide material support to their parents if adversity strikes, and the parents can join them in the city in their old age to benefit from the public hospital and other public services unavailable in the rural areas. Thus, while the private cost of a migrated child is 0, the return is by no means negligible. Through migration, optimum family size in the subsistence sector is brought yet closer to biological maximum.

While we know that the great mass of births comes from that half of humanity that is both rural and poor, very little quality empirical research has been done on the rationality of fertility in this context. Both detailed case studies and farm surveys are needed for this purpose. Such analyses should rank high on the agenda of research priorities.

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Interaction of Energy and Food Prices in Less Developed Countries: Comment

Panos A. Konandreas and Richard Green

Timmer, in a recent article in this *Journal*, examined the interaction between energy and food prices in less developed countries (1975). (This also applies to a previous article by Timmer in 1974.) His analysis was based on a simple macromodel consisting of an aggregate production and an aggregate consumption function for one of the major food grains. While this analysis reveals some interesting insights and suggests some important policy recommendations for developed and less developed countries alike, these conclusions are conditional on the magnitudes of price elasticity of demand (α) and energy elasticity of supply (γ), as we will show. Timmer failed to examine the conditions under which a new food-grain price equilibrium (called long-run equilibrium) is reached as a result of an exogenous change in the price of energy. A new equilibrium might not exist. In fact, it does not exist for most of the values of α and γ provided by Timmer. The purpose of this note is to clarify this issue within the framework of a dynamic model with lagged adjustment in two interrelated markets.

The simplified model used by Timmer with the time dimension introduced is

$$Q_{st} = A_s E_{t-1}^{\gamma}, \tag{1}$$

and

$$Q_{dt} = A_d P_{ot}^{\alpha}, \tag{2}$$

where Q_{st} and Q_{dt} = quantity of food grain produced and consumed in year t, respectively, E_{t-1} = energy input in year $t - 1$, P_{ot} = price of grain in year t, and γ and α = response elasticities of supply and demand with respect to energy input and price of grain, respectively. The three basic assumptions explicitly or implicitly made by Timmer are (*a*) in the short run, farmers treat the price of grain P_o and the price of energy P_e as given; (*b*) farmers do not foresee a change in the price of grain at period $t + 1$ as a result of a change in the price of energy input at period t; and (*c*) the supply of energy is independent of the conditions in the grain market, e.g., an increase in the price of grain will not affect the supply of energy.

Assuming the behavior of producers in the short run to be as described in (*a*) and (*b*) above, the assumption of profit maximization yields a short-run demand function for energy inputs:[1]

$$E_t = A_s^{\frac{1}{1-\gamma}} \gamma^{\frac{1}{1-\gamma}} P_{et}^{\frac{1}{\gamma-1}} P_{ot}^{\frac{1}{1-\gamma}}, \tag{3}$$

or

$$E_t = A P_{ot}^{a}, \tag{4}$$

where $A = A_s^{\frac{1}{1-\gamma}} \gamma^{\frac{1}{1-\gamma}} P_{et}^{\frac{1}{\gamma-1}}$ and $a = \dfrac{1}{1-\gamma}$.

The new price level of food grains at $t + 1$ is determined by equating the demand and supply functions

$$A_d P_{ot+1}^{\alpha} = A_s E_t^{\gamma}, \tag{5}$$

$$P_{ot+1} = A_s^{\frac{1}{\alpha}} A_d^{-\frac{1}{\alpha}} E_t^{\frac{\gamma}{\alpha}}, \tag{6}$$

or

$$P_{ot+1} = B E_t^{b}, \tag{7}$$

where $B = A_s^{\frac{1}{\alpha}} A_d^{-\frac{1}{\alpha}}$ and $b = \dfrac{\gamma}{\alpha}$. Substituting equation (4) into equation (7) gives

$$P_{ot+1} = B A^{b} P_{ot}^{ab}. \tag{8}$$

Equations (4) and (7) describe the dynamic behavior of the system.

After n periods the price of grain and the resulting demand for energy are

$$P_{ot+n} = A^{b\sum_{r=0}^{n-1}(ab)^r} B^{\sum_{r=0}^{n-1}(ab)^r} P_{ot}^{(ab)^n}. \tag{9}$$

and

$$E_{t+n} = A^{\sum_{r=0}^{n}(ab)^r} B^{a\sum_{r=0}^{n-1}(ab)^r} P_{ot}^{a(ab)^n}. \tag{10}$$

This system is stable if P_{ot+n} converges to an equilibrium, which is the case if and only if

$$\lim_{n\to\infty} \sum_{r=0}^{n} (ab)^r \text{ and } \lim_{n\to\infty} (ab)^n$$

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[1] By assumption (*b*), that is, producers apply a certain level of energy inputs with the anticipation that output price in the next time period (harvest time) is the same as the current output price, the expected profit at period $t + 1$ is given by $\Pi_{t+1} = P_{ot} Q_{st+1} - P_{et} E_t$. Maximizing this expression with respect to E_t yields equation (3). An error in Timmer's article in the derivation of the expression for E_t is carried forward in the other relationships.

exist. Both of these limits exist if and only if $|ab| < 1$, in which case

$$\lim_{n\to\infty} \sum_{r=0}^{n} (ab)^r = \frac{1}{1-ab} \text{ and } \lim_{n\to\infty} (ab)^n = 0.$$

Therefore, the condition that makes the system stable is $|ab| < 1$ or equivalently

$$(11) \qquad \left|\frac{\gamma}{\alpha(1-\gamma)}\right| < 1.$$

Assuming the above condition is satisfied, then the equilibrium (called long-run equilibrium) levels of the price of food grain, demand for energy input, and grain supply are, respectively,

$$(12) \qquad P^*_o = \lim_{n\to\infty} P_{ot+n} = A^{\frac{b}{1-ab}} B^{\frac{1}{1-ab}},$$

$$(13) \qquad E^* = \lim_{n\to\infty} E_{t+n} = A^{\frac{1}{1-ab}} B^{\frac{a}{1-ab}},$$

and

$$(14) \qquad Q^*_s = A_s E^{*\gamma} = A_s A^{\frac{\gamma}{1-ab}} B^{\frac{a\gamma}{1-ab}}.$$

Substituting for A, B, a, and b into equations (12), (13), and (14) gives

$$(15) \qquad P^*_o = \gamma^{\frac{\gamma}{\alpha(1-\gamma)-\gamma}} A_s^{\frac{1}{\alpha(1-\gamma)-\gamma}} A_d^{\frac{\gamma-1}{\alpha(1-\gamma)-\gamma}} P_{et}^{\frac{\gamma}{\gamma+\alpha(\gamma-1)}},$$

$$(16) \qquad E^* = \gamma^{\frac{\alpha}{\alpha(1-\gamma)-\gamma}} A_s^{\frac{\alpha+1}{\alpha(1-\gamma)-\gamma}} A_d^{\frac{1}{\alpha(\gamma-1)+\gamma}} P_{et}^{\frac{\alpha}{\gamma+\alpha(\gamma-1)}},$$

and

$$(17) \qquad Q^*_s = \gamma^{\frac{\alpha\gamma}{\alpha(1-\gamma)-\gamma}} A_s^{\frac{\alpha}{\alpha(1-\gamma)-\gamma}} A_d^{\frac{\gamma}{\alpha(\gamma-1)+\gamma}} P_{et}^{\frac{\alpha\gamma}{\gamma+\alpha(\gamma-1)}}.$$

The above equilibria exist only if the stability condition (11) is satisfied. If condition (11) does not hold, equilibrium is never reached and the system explodes. Timmer failed to notice this important point even though he obtained the same equilibrium expressions.[2] His expressions were derived by a mere substitution, and he failed to distinguish the time component involved. Implicit in his derivation was the assumption that, for large n, $P_{ot+n+1} = P_{ot+n}$, which implies that convergence was assumed or else that the system was forced to converge.

It is interesting to explore the stability region of the system, for the whole spectrum of elasticities, α and γ. Table 1 provides the values of the "stability" variable $\frac{\gamma}{\alpha(1-\gamma)}$ for different values of α and γ. The values of table 1 are graphed in figure 1. For any $\gamma < 0.5$, there exist several values of α that make the system stable. However, for $\gamma \geq 0.5$, no value of α results in a stable system. Timmer, in illustrating the differences in the elasticities between the short and long run, used $\gamma = 0.25$ (for which he cites another work by Timmer and Falcon, to which the authors did not have access, for this empirical evidence) and $\alpha = -0.20$. The "stability" variable for these values of γ and α becomes $\left|\frac{\gamma}{\alpha(1-\gamma)}\right| = 1.25 > 1$. Therefore, the system is unstable, long-run equilibrium does not exist, and thus a comparison between short and long run is meaningless. Accepting the empirically supported value of $\gamma = 0.25$ gives very discouraging results. The system converges only if the price elasticity of demand is at least 0.35 in absolute value and even in this case equilibrium will not be reached until after a considerable period of time. Price elasticities of the demand for rice for Asia range between -0.10 and -0.30 (Rojko, Urban, and Naive). For none of

[2] Note again the minor differences in the exponents that are the result of an error in Timmer's original article.

Table 1. Values of $\left|\frac{\gamma}{\alpha(1-\gamma)}\right|$

Value of γ	Value of α -0.05	-0.10	-0.20	-0.30	-0.50	-1.00
0	0	0	0	0	0	0
0.05	1.053	0.526	0.263	0.175	0.105	0.053
0.15	3.529	1.765	0.882	0.588	0.353	0.176
0.25	6.666	3.333	1.666	1.111	0.666	0.333
0.50	20.000	10.000	5.000	3.333	2.000	1.000
1.00	∞	∞	∞	∞	∞	∞

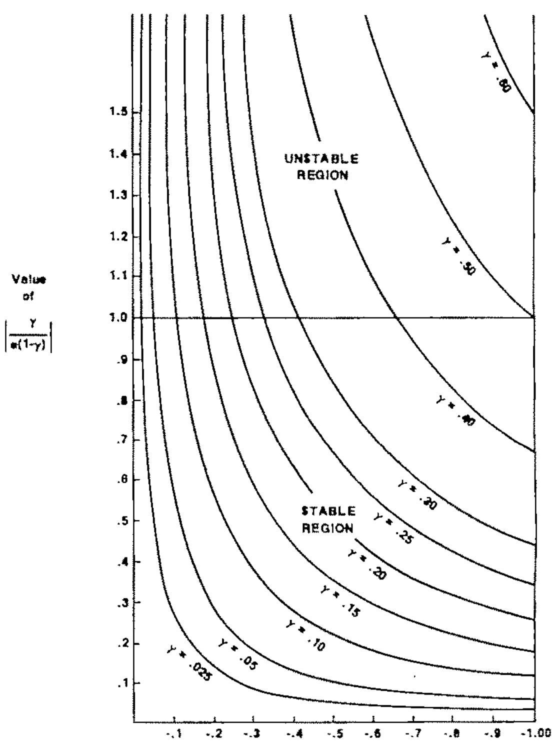

Figure 1. Relationship between α and γ in the stable and unstable regions of the model

these values of α (assuming $\gamma = 0.25$) is the system stable.

Although this analysis provides some clear insights into the dynamics of grain production and prices, one should be aware of the *ceteris paribus* conditions of the model. As Timmer points out, the effect of other variables influencing supply and demand should be examined. Substitution between energy and nonenergy inputs due to changes in relative prices, technological changes in grain production, and shifts in the demand due to population, income, and tastes have been ignored. Therefore, conclusions from this kind of model are qualitative in nature, indicating the tendencies of the effects of a change in the energy component, and one should refrain from any quantitative suggestions. A much more comprehensible model, empirical in nature, would be required for such an analysis.

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Interaction of Energy and Food Prices in Less Developed Countries: Reply

C. Peter Timmer

I am indebted to Konandreas and Green for carefully setting forth the existence and stability conditions for long-run equilibrium for the simple macromodel I used to examine some interrelationships between energy and food prices in LDC's. The authors are quite right. I assumed such an equilibrium existed and simply solved for it. Fortunately, our answers are the same.

The addition that Konandreas and Green make is the delineation of production and consumption parameters that are consistent with a stable long-run equilibrium. Unfortunately, the parameters used in the original article did not meet this criteria, although those used in the most recent version (Timmer), based on much more reliable empirical study (David) than the original (Timmer and Falcon), are consistent. Of course, inconsistency of empirical parameters with long-run equilibrium for the macromodel can be as easily interpreted as a failure of Cobb-Douglas specifications to hold over broad ranges than as a case of incorrect parameters. This reinforces the observation that the macromodel primarily offers qualitative perspective on the energy-food price relationship.

In his discussion when the paper was originally presented, Castle argued that "maximum physical product" had been wrung from the model and that only careful empirical study could carry us much further (p. 246). I agreed with both points at the time, and now Konandreas and Green make the same plea. After consideration of possible empirical applications, I now think that the only purpose of the model was to remind us that we all live in an interdependent world where everything affects everything else. It is an elementary point but one that is frequently forgotten. Attempts to quantify it are not likely to be very rewarding.

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Some Problems in Estimating the Demand for Outdoor Recreation: Comment

Jack L. Knetsch and Frank J. Cesario

In an interesting discussion of attempts to estimate the demand for outdoor recreation facilities, McConnell outlines the importance of the value placed on time as it influences decisions to make trips to recreation areas.[1] It is suggested that because time can be expected to have a negative influence on such decisions, estimates of demand curves derived using the travel-cost method are likely to be seriously biased unless models explaining trip quantities include a measure of total time of the outing rather than just the time incurred during travel. We do not think that this is necessarily the case. Disagreement in points of view may be due in part to a possible misinterpretation by McConnell of the mechanics of the travel-cost method and the rationale underlying it and in part to the failure of McConnell's (admittedly) simple model to capture the essence of alternative ways in which people may actually make decisions.

People contemplating a trip to a recreation facility presumably take account of both the money costs and the time costs, the latter reflecting total time of travel as well as duration of stay at the site. Certainly the total time commitment is a consideration having an important bearing on trip frequencies. However, this phenomenon is reflected in the observed numbers of people going to the site from different areas; i.e., people facing a two-hour drive to a facility for a day's outing weigh the whole days's time spent on this activity against the use of this same time in visiting alternative opportunities that may be located at different distances away or against doing something else entirely. Again, the point that seems to have been overlooked is that the observed visit frequencies are the outcomes of these weighting processes.

To perhaps better illustrate the role of travel time in recreation trip decisions, two views of these decisions can be taken. First, on any given outing it may be hypothesized that recreation seekers compare options for performing similar activities.[2] For example, on hot summer days the choice is generally between going to swimming pool A or swimming pool B; in winter periods, the choice is between skiing area A and skiing area B, and so on. The choice of an activity is the initial decision and the choice of where to go is a second decision, conditional upon the first. In these typical cases it is difficult to envision that the time spent on site would be considered as anything but fixed and independent of location. The relevant tradeoffs are between the attractiveness of alternative areas and the cost (time and money) of reaching them.

Second, in contrast to the first case, at the other extreme it might be argued that the time on site may diminish as the travel distance increases, thereby implying that there is a fixed total time allocated to a particular outing—say, a few hours, an afternoon, or a whole day. This assumption, which also might be considered as quite realistic, again implies that the distribution of visits to sites is determined by travel costs of which time cost is a major component.

Both of the above assumptions appear to be reasonable and it remains for empirical work to shed light on which one best describes actual behavior in different situations. But the main point remains that it is not the lack of an accounting for total time of the whole trip that is the source of difficulty in obtaining reasonable estimates of demand curves using the travel-cost method.

The so-called travel-cost method makes use of a visit-estimation model capturing the relationship between the number of trips from varying origins and the generalized costs of making these trips. A demand schedule is then imputed from this visit-estimation model by hypothesizing increasing costs to visits and estimating the consequent expected decreases in visitation. If only the money costs of travel are used in the analysis, the resulting demand and benefit estimates are subject to a serious bias (Cesario and Knetsch). This bias is caused by the implicit assumption that the only reason underlying visit rate (i.e., visits per capita) variations between origins of trips located at varying distances away from a park is the difference in money outlays. Of course, this is not likely to be the case. In particular, the time required to travel different distances

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[1] In addition to the travel time issue, McConnell addresses two other important issues in recreation demand modeling: choice of an appropriate unit for measuring consumption and choice of an appropriate specification of the demand function. We do not comment here on these other issues.

[2] The focus here is on recreation trips that are made within the framework of fixed total time budgets. Thus, this analysis is not useful for comparing, say, an afternoon outing with a trip of several days' duration.

would be a major reason for the observed variation in visit rates, an assertion that is well supported both theoretically and empirically.

Thus, when the model predicts that numbers of visits will decline with increased money costs, the decrease is consistently overestimated if time cost is not included. In reality, the visit rate for any origin is expected to decrease with an increase in money cost but not to the extent indicated by the observed distance-decay function (which in essence reflects only effects of money costs) since time costs remain constant at the original level. For instance, with respect to a particular origin, if money costs equivalent to an added distance of 30 miles were added to money costs associated with an original distance of 20 miles, the visit total for the origin in question could not realistically be expected to be that of an origin 50 miles from the park. The new money outlay would be that associated with travel over 50 miles, but the time cost is still that which was associated with the original 20 miles.

The demand curve is then conservatively biased for all points except the zero "price" point. More visits would in fact be expected for each assumed money cost increase than would be calculated directly from the model. The problem of demand curve bias is therefore due to ignoring travel time and not from a failure to take account of the total time needed for the whole enterprise. While better insights into why demands for the use of recreation areas might well result from more attention to the effects of time constraints, the problem of dealing with travel time in imputing demand curves seems to depend on determining its relative weight in a generalized cost function.

Some empirical work is beginning to provide interesting results in establishing the needed values. A study by Mansfield suggests that the weight or importance of time in overcoming greater distances to recreation sites is perhaps of greater importance than the money costs involved. As he notes, the issue is the disutility of time traveling to a recreation facility and not that of traveling, say, within a park. Some further travel time results with implications for recreation modeling are provided by Cesario in which the results of a number of travel time studies are reported. The results suggest that times values from one-fourth to one-half of wage rates might well be appropriate on the average. The impediment of time might well vary, for example, with the nature of the scenery or local amenity or other factors. Travel time would be less of a burden for a journey through semispectacular landscapes than one through more drab countryside, and the weights for the variable measuring the importance of travel time could in principle at least reflect this. Future research should provide some valuable insights into these questions.

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Some Problems in Estimating the Demand for Outdoor Recreation: Reply

Kenneth E. McConnell

The Knetsch and Cesario comment is valuable because it encourages thinking about how recreationists make decisions. Knetsch and Cesario take issue with my result that the cost of total time, not simply the cost of travel time, be added to the per unit travel costs of a trip.

In their comment, Knetsch and Cesario raise two basic issues. (*a*) A more realistic model would permit time on site to vary as per trip costs vary. (*b*) In a two-stage decision-making process, the recreationists choose first the amount of time per activity and second at which site to participate in the activity. Knetsch and Cesario assert that in such a framework time spent on site is considered fixed and hence not part of the costs of recreating. I will discuss each of these issues separately.

A utility maximization model is best at bringing out the implications of assumptions. It abstracts from the many realistic details that are important for decision making. In my paper, in order to concentrate on the demand for trips, I assumed that trips are of fixed length. The conclusions are not based on the assumption that the length of a trip is fixed. The model can be modified so that time spent per trip (a_j) is also a choice variable. However, even when the time spent per trip is a choice variable, it can be demonstrated that the recreationists consider the opportunity cost of the time used by the whole trip and not simply the travel time.

In my paper, the decision-making process is such that the individual chooses simultaneously which site to visit and how many trips to take. The recreationist compares in his mind the enjoyment he gets from participating in an activity at a particular site with the opportunity costs of the time and money required by a trip. It is important that the individual consider both the activity and the site simultaneously, because the same activity engaged in at two different sites may result in substantially different experiences. For example, swimming at a crowded pool is a very different experience from swimming in a lake in a natural environment with few people. Each trip to a particular site must be worth at least the travel cost plus the opportunity cost of the total time spent on the trip. Otherwise, the individual would not go. This can be seen clearly by rewriting equation (8) of my paper (p. 331):

$$(1) \qquad (\partial U/\partial r_j)/\lambda = c_j + a_j m_T.$$

The term on the left is marginal money value of a trip to the jth site. The term on the right is the marginal cost of a trip to the jth site. For the recreationist to ignore the total time spent on the trip, the opportunity value of time (m_T) must be 0.

Knetsch and Cesario have outlined a rather different process of decision making, which involves two stages. First, the recreationists decide in which activity (camping, swimming, etc.) they will engage. Second, they decide on which site they will engage in the activity. By making the assumptions of the decision-making process explicit, it can be demonstrated that the value of total time and not simply travel time should be measured as part of the cost of the outing.

Suppose that the individual has completed the first stage of decisions by choosing the optimal quantities of each recreation activity per period, denoted by T^*_i—the optimal number of trips of swimming, skiing, etc. The second stage of decision making is investigated, where the individual chooses r_{ij}, the number of trips of the ith activity at the jth site. (For simplicity, we assume that all trips are the same length so that the $a_j = 1$.) Let utility depend upon r_{ij} and let c_{ij} represent the travel costs required to engage in activity i at site j. The second stage problem is to maximize with respect to r_{ij}:

$$U(r_{ij}) - \lambda(\sum_i\sum_j c_{ij}r_{ij} - y^*) - \sum_i\psi_i(\sum_j r_{ij} - T^*_i),$$

where y^* = the amount of income to be spent on recreation. At the optimum,

$$(2) \qquad \partial U/\partial r_{ij} = \lambda c_{ij} + \psi_i \text{ for all } i \text{ and } j.$$

Condition (2) states that the recreationist engages in activity i at site j up to the point when its marginal utility ($\partial U/\partial r_{ij}$) equals the utility opportunity cost of expenditures plus ψ_i. The multiplier ψ_i is interpreted as the marginal utility of another trip in the ith activity. It is the opportunity cost of going to site j rather than another site. Then equation (2) can be given exactly the same interpretation as equation (1). The optimum allocation of time and income to r_{ij} is such that the marginal value of r_{ij} (in money terms) equals the opportunity cost of time plus the

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out-of-pocket costs of getting to the site. The cost of a trip, whether one approaches it via the Knetsch-Cesario two-stage decision or via a simultaneous consideration of site and activity, should include the opportunity costs of the total time on the trip.

Although this two-stage approach reaches the same conclusion, it seems unrealistic. It requires that the recreationists choose their activity without considering the site. Having selected the activity, recreationists then choose from the sites where the activity is available. At the second stage, the recreationists must choose the site to visit regardless of the quality of available sites and despite the fact that they could do something else with their time. Such a decision-making process has the implication that aggregate participation in any recreation activity is independent of congestion or other site quality variables of the activity. In fact, site quality variables would affect only the distribution of trips among sites and not the total number of trips.

The result that rational allocation requires the recreationist to consider the opportunity cost of total time is useful because it permits us to reinterpret benefit estimates that omit the total cost of time. The result may also be useful in explaining negative or insignificant income elasticities that researchers occasionally obtain for various recreational sites. Time costs and income are highly correlated. At some point, as income increases, the negative effect of the higher cost of time may outweigh the positive effects of higher income. However, a regression that includes income and omits the cost of time would impart a substantial downward bias to the income coefficient.

In conclusion, the opportunity cost of the recreationists' time is important in the decision-making process and should be considered as part of the per unit cost of a trip. Not only does it improve measurement of net benefits but it helps in understanding the determinants of recreation participation.

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The AAEA Membership: Employment and Mobility Patterns

Anne E. Peck and Emerson M. Babb

Perceptions of one's profession are very subjective. For agricultural economists this subjectivity is increased because of the diversity of employment opportunities both within the profession and within even the academic component of that profession. Thus, data that can be used to provide more objective views are of interest, making individuals aware of more general patterns within the profession. Both Helmberger and Boddy have provided data on the market situation for agricultural economists in 1970, while Gray (1973a, b) has offered some interesting analyses of changing interest areas within the profession. This note summarizes data obtained in the 1971 survey of members of the American Agricultural Economics Association (AAEA). The first section summarizes this data to describe general employment patterns of agricultural economists, defined here as members of the AAEA. Then, some characteristics of the mobility of members are considered. Particular interest focuses upon academicians, and several measures examine the extent of inbreeding on faculties of agricultural economics.

The AAEA membership data that were published as the "Handbook-Directory" of the AAEA in 1972 pose several problems for these analyses. Initially, all student members and all incomplete responses were eliminated. The remaining 2,075 members constitute this sample of the agricultural economics profession. It is a biased sample, representing mostly individuals who have obtained advanced degrees. Thus, the analyses should be extrapolated to the profession at large with a great deal of caution. The data constitute a snapshot of the profession, and that picture is now somewhat dated. Consequently, the material presented here is primarily descriptive. Interesting patterns do emerge, however, and these may stimulate others to seek further for explanations.

Current Employment Patterns

General characteristics of employment patterns and education levels of the AAEA members are summarized by the data in table 1. AAEA members are mainly advanced degree holders, employed in either academics or some level of the government. Approximately 96% of the AAEA members held an advanced degree, while nearly three-quarters of them held a Ph.D. degree. Viewed by employment categories, nearly 65% of the members were academics and 24% were in government employment.

These concentrations underline the biases involved in viewing the AAEA members as a representative sample of the agricultural economics profession. Data provided by Helmberger from the 1970 American Science Manpower survey sponsored by the National Science Foundation (NSF) can be used to approximate the extent of this bias. The NSF survey attempts to achieve a broad representation of professionals in specified areas. In addition to the membership lists of the professional organization, their lists contain individuals attending professional meetings, those subscribing to professional journals, and alumni of various institutions.[1] For agricultural economists thus defined, only 55.5% were academics while 30% were employed in government in 1970. Interestingly, the NSF data showed that 93.5% of agricultural economists had advanced degrees. The concentration at the Ph.D. level was not as high as that in the AAEA data, however, with only 57.5% of the surveyed individuals holding Ph.D.'s.

Within the degree categories, some similarities appear between the AAEA members' survey and the NSF survey. For instance, of AAEA members with Ph.D.'s, 73.4% were employed as academics in 1971. The NSF survey data showed 72.5% of Ph.D. holders were academics in 1970. Similarly, of the AAEA members with Ph.D.'s, 5.7% were employed in business while 19.1% held jobs in government. The analogous figures from the NSF survey were 2.6% and 19.5%, respectively. Thus, individuals with Ph.D.'s appear to be proportionately represented in the AAEA survey. With this result, further analysis of current employment patterns considers only those AAEA members who have received Ph.D.'s, that is, only that portion of the

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[1] In 1970, the NSF survey classified 1,501 individuals as agricultural economists. This compares with the 2,075 AAEA members represented here. The difference is primarily in definition of an agricultural economist. Individuals with specialties in international trade, economic development, and econometrics were classified as economists in the NSF reports. No information on an individual's specialty was available in the AAEA survey.

Table 1. The Distribution of the AAEA Members by Current Employment and by Highest Degrees, 1971

	Highest Degree Held			
Current Employment	B.S.[a]	M.S.	Ph.D.	Total
Academic	15	188	1,135	1,338
Business	25	72	89	186
Government	33	170	295	498
Nonprofit institutions	1	2	17	20
Other[b]	3	20	10	33
Total	77	452	1,546	2,075

[a] Includes five members who indicated that no degree had been received. Of these, four were currently employed in academic institutions and the other was employed in government.
[b] Other includes self-employed, retired, and types of employment not identified.

sample that appears most nearly representative of the profession.

In the AAEA survey, individuals were asked to indicate where they had taken their various degrees. One hypothesis is that graduate training and occupation choice are independent. Equivalently, the hypothesis is that the institution from which a degree was taken had no influence on the job choice. Table 2 summarizes the current employment data by school from which the degree was obtained. Only schools that had given degrees to more than five AAEA members were separately listed. Because of the negligible importance of two of the employment categories, nonprofit institutions and other, they have been omitted here. The figures in the employment categories are percentages, making comparisons among schools more clear. However, the last column of data in this table contains the actual total number of AAEA members who had Ph.D.'s from these schools. Thus, the relative contribution of each of these schools in supplying Ph.D.'s can be easily seen.

A chi-squared test was performed to test the hypothesis of independence between current employment and the school from which the Ph.D. was received. The hypothesis was rejected at the 4% level. Thus, there were significant differences in the employment choices among the graduates of the individual institutions. The reader may find the school-by-school data interesting though no clear patterns emerge. Six schools (Purdue, Iowa, Michigan State, Minnesota, Cornell, and Wisconsin) clearly dominate as suppliers of AAEA members with Ph.D.'s. A total of 733 members received their degrees from one of these institutions, that is, nearly one-half of the total membership who have Ph.D.'s.

Mobility Patterns

The 1971 members' survey was not designed to provide data for an analysis of individual's movement either between or within particular employment categories. The questionnaire provided a relatively small space for individuals to describe previous employment (Handbook-Directory, pp. F–G). Furthermore, respondents were not explicitly encouraged to include details on all previous positions.[2] Thus, the data used in the following analyses are likely to be biased downward, underestimating mobility within the profession. The extent of this bias is unknown. All reported previous employment was counted in an effort to minimize the extent of the bias. For individuals who were currently academics, sabbatical and other leaves of absence were counted as previous jobs. For analysis of some questions of mobility, such as of the criteria upon which a job-change decision was made, this procedure would be inappropriate. However, interest here centers on diversity and movement within the profession, and leaves of absence contribute to both these aspects of mobility.

The data in table 3 summarize individuals' reported current and previous employment. Most obviously, they suggest that academicians are relatively mobile, both among schools and among occupations. Almost 70% of the individuals who were currently at universities had been employed at other universities. This no doubt reflects the effects of including leaves of absence as previous employment. More interestingly, of those currently employed in other occupations, a relatively large percentage had been employed as academicians previously. In fact, university employment is nearly always the largest category of previous employment. The only exception is with government employees, a larger percentage of whom had held some other position in government. These data suggest that AAEA members are relatively mobile individuals within the profession.

The academic component of the membership appears to be highly mobile, even if the effects of the various data problems are considered. This suggests that faculties of agricultural economists are quite diverse, in general, bringing together a wide range of backgrounds and experiences. The remainder of this analysis attempts to investigate this hypothesis. Only AAEA members who are currently academics are included. Further, these members are sorted by schools; thus, the unit of observation is a faculty of agricultural economists. The implicit assumption is that a faculty can be represented by its AAEA members. For an individual school, this assumption may cause some difficulties. Thus, the major results here are presented in terms of regional aggregates of schools. Selected information on individual schools is presented in table 4.

With the AAEA member data, three measures of

[2] There are some studies of the mobility of academicians more generally. Sample questionnaires designed specifically to investigate mobility questions are available in Marshall, pp. 139–42, and Brown, pp. 199–205.

Table 2. Employment Patterns of the Graduates of Major Ph.D.-Granting Institutions, AAEA Members, 1971 [a]

School	Percentage of Ph.D.'s Employed in: Academics	Business	Government	Total Number of AAEA Members with Ph.D.'s from Specified Institution [b]
California [c]	76.1	8.7	12.0	92
Stanford	83.3	0	8.3	12
Connecticut	77.8	0	22.2	9
Florida	75.0	8.3	16.7	12
Hawaii	71.4	0	28.6	7
Illinois	65.4	7.7	25.6	78
Chicago	78.0	0	17.1	41
Purdue	70.8	12.4	16.8	113
Iowa State	75.8	3.8	17.2	157
Kansas State	70.0	10.0	20.0	10
Kentucky	82.4	0	17.6	17
Louisiana State	88.9	11.1	0	9
Maryland	33.3	6.7	60.0	15
Harvard	59.6	5.3	29.8	57
Michigan State	68.5	5.6	23.4	124
Minnesota	75.7	2.8	20.6	107
Missouri	69.2	5.1	25.6	39
Montana State	77.8	0	22.2	9
Nebraska	80.0	0	20.0	15
Cornell	67.4	10.1	18.6	129
N. Carolina State	80.4	0	19.6	56
Ohio State	75.0	9.7	13.9	72
Oklahoma State	79.6	4.1	16.3	49
Oregon State	75.9	3.4	13.8	29
Pennsylvania State	76.9	5.1	17.9	39
Tennessee	80.0	10.0	10.0	10
Texas A&M	83.3	0	16.7	18
Washington State	75.0	12.5	12.5	16
Wisconsin	74.8	1.0	24.3	103
Simple average [d]	74.0	4.9	19.6	
Weighted average [e]	72.8	5.7	19.6	
All other schools	82.4	5.9	11.8	102
Weighted average for total population	73.5	5.7	19.1	1,546

[a] The figures in this table pertain to only those members of the AAEA who had obtained Ph.D's. Only institutions that granted more than five Ph.D.'s to AAEA members are specifically listed here. All other institutions are aggregated in the "Other" category.
[b] The percentage figures may not add to 100 for every school as two employment categories, nonprofit institutions and other, have been omitted. However, the figures for total number of graduates, entered in the last column, include individuals in those two categories as well as the three primary ones.
[c] Includes both Berkeley and Davis campuses.
[d] The average percentages for the twenty-nine schools listed above.
[e] Weighted average percentages take into account relative sizes of the institutions being aggregated. The unit of observation is the individual rather than the school.

Table 3. Mobility of AAEA Members among Occupational Groups

Current Employment Status	Percentage of AAEA Members Who Have Held Positions in an Employment Status Different from Current Position [a]: Academic	Business	Government	Foundation	Other
Academic	68.7	8.0	25.7	1.7	6.3
Business	41.6	39.5	24.3	1.1	5.4
Government	44.2	9.4	57.8	1.9	5.0
Foundation	60.0	10.0	25.0	25.0	10.0
Other [b]	51.5	9.1	30.3	0	30.3

[a] For example, for members currently employed as academics, 68.7% have held positions in other academic institutions, 8% have had business experience, 25.7% have had government experience, and 1.7% have had foundation experience.
[b] Other includes self-employed, retired, and types of employment not identified.

Table 4. Selected Characteristics of Faculties of Agricultural Economics Defined by Their AAEA Members, 1971

School	Members	Staff with Ph. D.'s from: School where Now Employed	Staff with Ph. D.'s from: School in Same Region as School where Now Employed	Staff with at Least One Degree from School where Now Employed	Staff Who Have Never Held a Position Outside State of Current Position
		%			
Auburn	15	6.7	40.0	46.7	53.3
Arizona	15	13.3	13.3	20.0	40.0
Arkansas	12	0	16.7	50.0	58.3
California[a]	39	23.1	25.6	38.5	43.6
Stanford	10	30.0	40.0	50.0	36.4
Colorado State	15	0	0	20.0	13.3
Connecticut	14	7.1	14.3	35.7	35.7
Florida	38	5.3	18.4	10.5	34.2
Georgia	20	5.0	45.0	25.0	35.0
Hawaii	10	10.0	60.0	10.0	30.0
Idaho	13	0	15.4	7.7	38.5
Illinois	51	27.5	64.7	45.1	41.2
Purdue	48	43.8	72.9	56.3	18.7
Iowa State	39	41.0	56.4	59.0	41.0
Kansas State	25	8.0	8.0	56.0	52.0
Kentucky	29	20.7	24.1	55.2	41.4
Louisiana State	18	11.1	16.7	16.1	66.7
Maine	12	0	50.0	0	41.7
Maryland	18	5.6	33.3	27.8	44.7
Massachusetts	12	16.7	41.7	33.3	41.7
Michigan State	39	17.9	61.5	36.0	53.8
Minnesota	47	42.3	72.3	57.4	36.2
Missouri	39	10.3	43.6	46.2	30.8
Montana State	14	7.1	14.3	57.1	50.0
Nebraska	16	18.6	25.0	43.8	31.3
New Mexico State	15	0	13.3	26.7	40.0
Cornell	40	45.2	50.0	65.0	37.5
N. Carolina State	34	23.5	26.5	52.9	52.9
N. Dakota State	19	0	26.3	58.0	36.8
Ohio State	46	34.8	67.4	60.9	39.1
Oklahoma State	26	23.1	26.9	46.2	38.5
Oregon State	23	8.7	17.4	26.1	34.8
Penn State	30	20.0	30.0	46.7	36.7
Clemson	12	8.3	50.0	41.7	16.7
S. Dakota State	14	14.3	21.4	42.9	50.0
Tennessee	25	12.0	28.0	36.0	60.0
Texas A&M	29	10.3	20.7	41.4	34.5
V.P.I.	20	10.0	20.0	30.0	55.0
Washington State	10	11.1	22.2	14.8	40.7
West Virginia	10	0	10.0	30.0	30.0
Wisconsin	35	42.9	51.4	65.7	31.4
Wyoming	12	0	25.0	33.3	8.3

Note: Only schools with at least ten AAEA members on their staffs are included.
[a] Includes both the Davis and Berkeley campuses.

diversity of staffs were constructed. The first, the percentage of staff members who had received their Ph. D.'s from that same school, is the traditional measure of inbreeding. The second, the percentage of staff members who had received at least one degree from that same school, measures inbreeding with a somewhat broader definition. Finally, information on previous employment was utilized to calculate the percentage of a department's staff who had never held a position outside that state.

Table 5 presents the results of these calculations, averaged over five regional groupings of individual schools. Schools in the North Central region are clearly the most inbred. Nearly a third of their staffs have received their Ph. D.'s from the school of their current employment, and more than 50% of their staff have taken at least one degree there. These are nearly twice the averages for the other regions. The rankings of the other groups of schools change considerably between these two measures. The similarity of the measures and the changing rankings suggest that an element of individual choice may be involved in returning to a school where a degree had been obtained. Hiring of a

Table 5. Diversity in Faculties of Agricultural Economics Departments, AAEA Members, 1971[a]

Region	Staff with Ph.D.'s from School of Current Employment	Staff with at Least One Degree from School of Current Employment	Staff Never Worked Outside of State[b]
		%	
Northeast[c]	15.7	34.8	39.7
South	10.1	35.8	45.8
North Central	32.6	53.3	36.5
Mountain, Plains, and Southwest	7.9	37.8	36.1
Pacific	16.6	27.9	37.1

[a] Averaged over schools in each region with more than ten AAEA members. School specific data are reported in table 4.
[b] Experience outside of state includes any government or business position held previously, as well as other academic positions.
[c] Northeast: Connecticut, Maine, Maryland, Massachusetts, Cornell, Penn State; South: Alabama, Polytechnic Institute, Arkansas, Florida, Georgia, Kentucky, Louisiana State, North Carolina State, Clemson, Tennessee, Virginia Polytechnic Institute, West Virginia; North Central: Illinois, Purdue, Iowa State, Michigan State, Minnesota, Missouri, Ohio, Wisconsin; Mountain, Plains, and Southwest: Arizona, Colorado State, Idaho, Kansas State, Montana State, New Mexico State, Nebraska, North Dakota State, Oklahoma State, South Dakota State, Texas A&M, Wyoming; Pacific: California, Stanford, Oregon State, Washington State, Hawaii.

department's own Ph.D. students to fill staff vacancies is often guided by policy decision within a department or a university. However loosely enforced, there usually are guidelines of some sort. This is not as often true when an individual has taken another degree, a B.S. and/or an M.S., from the school. Further, at least one study of academic mobility presented evidence of a tendency for academics to wish to return to a region they know, their "home" region.[3] Thus, the second measure may reveal the combined influences of departmental policies and individual desires.

The third measure of diversity of departments' faculties results in a completely different ranking of the schools. From the information available on previous employment, this measure provides an estimate of the percentage of staff members who appeared to have never worked outside of the state of their current employment. Graduate school experience was excluded, but business and/or government experience was considered sufficiently different from academics so as to be included as outside work experience. By this measure, the faculties of southern schools appeared to be least diverse. These same schools were not highly inbred, suggesting that there is a relatively low turnover rate in the faculties of these schools.

Taken together, the data in table 5 suggest a significant amount of regionalism in departmental faculties. If hiring of one's own Ph.D. students is not particularly excessive, perhaps there are significant intraregional trading patterns among schools within the various regions. The regional employment ratio constructed below provides an indication of the extent of trading among schools within each of the five regions. If each region were viewed as a single school, the ratio is simply the percentage of the staff of that school who obtained their Ph.D.'s there divided by the percentage of the graduates of that school in the total population of schools. Alternatively, it is the actual percentage of inbreeding given the population. The calculations in table 6 are all weighted averages, since concern is with distributions within the population of academics. Finally, using weighted averages allowed inclusion of all schools in each region, even those with less than ten AAEA members.[4]

From table 6, the North Central region is clearly the largest supplier of academics with Ph.D.'s. Fully 45% of AAEA members currently employed as academics received their Ph.D.'s from a North Central school. Since this region contains most of the largest schools, it is not unexpected that a large percentage (62.5) of staffs of these schools obtained their Ph.D.'s from schools in this same region. This gives a relatively low regional employment ratio of 1.4, that is, staffs of these schools are regionally inbred only 1.4 times the expected level of inbreeding given the population. The results for the southern schools are at the opposite extreme. While only 7.3% of all the academics in the AAEA sample received their Ph.D.'s from these schools, 25.7% of these schools' combined faculties had degrees from this region. This is 3.5 times the population distribution, implying an important tendency to hire within the region.

In an applied discipline such as agricultural economics, some regionalism of the staff is to be

[3] The study polled a sample of recent movers in all areas of academics. Individuals were asked to designate regions to which they desired to move. Generally, over half of the respondents desired to return to an area where they had been in school previously, either in high school, undergraduate, or graduate school (Brown, pp. 88–89).

[4] The regions are basically those defined by the schools in footnote c to table 5. Examples of schools included in these weighted averages that were omitted there are Harvard, Chicago, M.I.T., Nevada, New Hampshire, Rutgers, and Rhode Island. These schools have less than ten AAEA members on their staffs, but some have been important sources of members of the AAEA. Each of the previously omitted schools was counted in its appropriate regional aggregate.

Table 6. Intraregional Trading Patterns of Faculties of Agricultural Economics, AAEA Members Only, 1971

	Academics with Ph.D.'s from School in Region[a]	Staff of Schools in Region with Ph.D.'s from School in Region[b]	Regional Employment Ratio[c]
	%		
Northeast	12.6	38.3	3.0
South	7.3	25.7	3.5
North Central	45.1	62.5	1.4
Mountain, Plains, and Southwest	6.6	17.9	2.7
Pacific	8.9	27.3	3.1

[a] The percentage was calculated over the entire sample of AAEA members who are currently academics. Column does not add to 100 because some academics do not have Ph.D.'s and small domestic and all foreign schools have been omitted.
[b] Average taken over all schools in each region, weighted by the number of AAEA members on each school's staff.
[c] Column 2 divided by column 1.

expected. Production practices, cropping patterns, and even crops grown change substantially among regions. Furthermore, when the extension mission of many of these departments is considered, some regionalism is probably desired. How much is desirable is a question not addressed here. The evidence presented suggests that patterns differ substantially among regions. It suggests also that the market for academicians is very imperfect. Finally, much more information is needed to begin to put causes together with the observed differences.

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Publications

Books Reviewed

Committee on Agricultural Production Efficiency. *Agricultural Production Efficiency*. Washington: National Academy of Sciences, 1975, 199 pp., $6.50.

Events of the past three years have raised new questions about excess capacity in the U.S. farm production plant. Grain stocks have been worked off, partly by fortuitous expansion of world demand and partly by several years of diverting production potential into idled acres. At the peak, when stocks were drawn down, some 60 million acres available as reserve production plant were our insurance. Programs were modified in each of the last three years to employ part of the idled acres to rebuild some grain reserves. By 1975 all of the idle acres were permitted back in production.

We were then treated to a great shock. Only about 38 million of the 60 million acres apparently came back into production, despite record high prices. Stocks did not get rebuilt. What happened? The causes are not yet all sorted out. As one part of an explanation, the suspicion is beginning to emerge that productivity of this acreage in reserve may have been severely overestimated. The recent events also raise questions about whether we can rely on the estimate of natural resource specialists that we have some 30 million acres in other uses, which could be brought into cropland. A look at acreage in 1975 versus the 1920s would verify that our current cropland base is smaller than the earlier one. But if prices of commodities during 1973–75 do not stimulate significant land development, we must take another look at the economic potential. Was the high recent price level considered temporary by landowners, with a longer term expectation insufficient to support the investment? Or were our calculations of economic potential of cropland base in error?

The possibility that we have fewer units of idle land and potential cropland than we thought focuses added attention on the question of increasing productivity of our current acreage. That is the topic of the monograph under review. In 1971, the National Academy of Sciences constituted the Committee on Agricultural Productivity. Two avenues of concern were expressed. One was general—unease over two decades of increasing emphasis on putting new resources in areas outside agricultural production and on shifting from farm production to development and social problems within the agricultural research funds. The second and precipitating concern was the apparent slowing of the increase in agricultural productivity reflected in the U.S. Department of Agriculture productivity indices. The unprecedented grain exports, the disappearance of our grain reserves, and the energy crisis came while the study was underway. The reevaluation of the capacity of our idled and potential acres comes since publication of the monograph. All emphasize the timeliness of this report.

The book is a wide ranging "report to the public" on the status of agricultural productivity. It is extremely readable and well organized. An early chapter covers the concepts of productivity and efficiency and reviews the various partial and total productivity series produced by the Economic Research Service. It notes with concern the ERS habit of changing base periods or calculation procedures in this extremely vital series with little or no public announcement. In fact, revisions of this type canceled out the apparent productivity dip that was the concern precipitating the formation of the National Academy of Sciences committee. The report suggests a number of measures that could be used to improve the current series.

Two major chapters explore the social assistance to agricultural productivity and the social constraints imposed upon it. The committee emphasizes the need for clearer delineation of the tradeoffs in productivity versus social control in areas of regulation of environment, transportation, and other areas.

Additional chapters describe and evaluate agriculture and the energy situation in a lucid fashion. These provide some general hints on directions for future research. They note that plant agriculture is an energy capturer. Photosynthesis itself is able to gather about 1% of available sun energy. Some half of that is in economic parts of the plant. Net product from animals using these plant products is some 4% to 10% of the total energy in the feeds. They point out that cultural energy—in petroleum, fertilizers, etc.—is used 10 to 100 times more efficiently than is solar energy. The analysis both suggests an emphasis on improved capture of solar energy and an emphasis on plant and animal forms using cultural energy more efficiently. Altogether, the chapters provide a fascinating overview.

Other chapters review potential areas for re-

search breakthroughs in plant and animal areas in the near future, providing both a clear explanation and some guidance on priorities for the layman.

The committee concludes that productivity can continue to increase over at least a decade from known or nearly known sources. They contend that there are limits to which various biological processes can go but also emphasize that striking one limit often stimulates search in another direction, opening unforeseen opportunities. Contending that the lead time from discovery to application is about twenty years, the committee suggests increased funding is necessary for agricultural productivity research in the immediate future.

I would recommend this book to all economists interested in resource allocation in research. It provides a nontechnical insight into biological frontiers. It places energy flow in agricultural systems into better perspective than seen before. The work is broad, benefiting from a wide range of disciplines on the committee. The prestigious sponsoring organization should provide these views with an aura of legitimacy not available to the more traditional advocates of the agricultural establishment. The style of writing aids in making the arguments accessible to a wide variety of informal audiences. The analysis itself also provides an excellent starting place for reassessing priorities in use of existing agricultural production research funds.

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Grigg, D. B. ***The Agricultural Systems of the World: An Evolutionary Approach.*** **Cambridge: The University Press, 1974, ix + 358 pp; $24.00, $8.95 paper.**

Here we have a book with wonderful possibilities. From an author who has mastered such a wide scope of the literature on agricultural subjects drawing upon history, geography, and economics, we should take him at his word when he promises to attempt to "describe the chief characteristics of the major agricultural regions of the world and to attempt some explanation of how they came into being" (p. 1). Indeed, we are treated to a smorgasbord of descriptions of farming systems around the world, past and present. For this service alone the book is a valuable (and expensive, in hardback at least) addition to the library of anyone with even a passing interest in the subject. But the promise of learning "how they came into being" is not fulfilled. Perhaps the author's intentions were suggested in his subtitle, "An Evolutionary Approach"; unfortunately, evolutionary and historical explanations in agriculture are no more identical than they are in English history, where the genealogy of the royal family does not quite serve as an adequate history of the British Empire. Grigg's method is more genealogical or sequential, listing the stages in the evolution of farming systems.

True, there are glimpses of how things came to be. Demographic influences, subsidies, and tariffs as well as patterns of landholdings are recognized as important human influences in shaping the course of agricultural development; usually, however, human activity merely conforms to the imperatives of the existing price structure. The exceptions to this statement most frequently are found in the treatment of tropical agriculture, where more direct human intervention is given more prominence. Here, slavery, force, and other factors less amenable to the "evolutionary" treatment are given their due.

While other readers may share my disappointment in the gap between the performance and the promise of the book, they will probably agree that the mass of scholarship at Grigg's disposal makes him one of the very few people from whom such a promise could be taken seriously.

The arrangement of the book is very convenient. Each form of agriculture, such as plantations, dairying, etc., is studied in a separate section that is subdivided by its geographical variants. The latter, in turn, are described along with their "evolutionary" histories. This approach is most rewarding in the section on wet rice farming techniques, which dramatically vary among regions.

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Paige, Jeffrey M. ***Agrarian Revolution: Social Movements and Export Agriculture in the Underdeveloped World.*** **New York: Free Press, 1975, xiv + 435 pp., $15.95.**

This work begins as if it might be a Marxist analysis of the preconditions of revolution in export agriculture. While modern industry has not produced the homogeneous labor force of impoverished workers that Marx and Engels "predicted" (Paige's term, p. 33), much of the export agriculture in the third world appears to have created just such a labor force. By the fiftieth page we hear no more of Marx after having learned that the failure of the rate of profit to decline has allowed the capitalist employers to loosen the chains of exploitation that might have otherwise made any alternative other than revolution a hopeless prospect.

Nowhere does Paige mention Marx's few tantalizing references to the role of highly profitable colonial ventures in shaping the destiny of North Atlantic capitalism, a topic not extensively covered in *Capital,* which was essentially a model of a closed economy (see Rosdolsky, I, pp. 39, 74, and 95). But Paige does not demonstrate a believable concern with Marxist theory; rather his thesis is flatly conventional. For him, capitalism in general

does not lead to revolution, even in export agriculture. Only those variants that Paige terms "constrained capitalism" are conducive to revolution, that is, where landed elites restrict the workings of the market (p. 320).

Paige's analysis of "constrained capitalism" consists in developing a theory of how "variations in the principal source of income of both cultivating and noncultivating classes" (e.g., wage labor, share cropping, etc.) " 'influences' their political behavior in conflict situations" (p. 334). His analysis is based on a model of a "calculus of force" that is "just as orderly and rational . . . as the principles of economics" (p. xi). Indeed, Paige's approach is much like what one would expect from an economist, except that Paige has to go to greater lengths to develop a data base. Reports of "events" in which agricultural laborers in major exporting sectors engaged in collective noninstitutional group-based activity were coded according to various characteristics. These codes then become the dependent variable to be explained by the form of agricultural organization. Revolutionary socialist events are "moderately correlated ($r = 0.39$) with sharecropping systems, agrarian events (such as land seizures, MP) are strongly correlated with commercial hacienda systems ($r = 0.51$), and labor events (such as strikes, MP) are strongly correlated with plantation events" (p. 104).

These broad results are followed by case studies of Peru, Angola, and Vietnam in which these general results are amplified with a detailed analysis of his "calculus of force." Here, Paige demonstrates how peasants and agricultural workers in these nations assess the benefits and risks of political action. The detailed descriptions of the organization of agricultural enterprises in these nations make up the best of Paige's book. Not only are his choices of cases timely, the variation of agriculture within these nations neatly supports his thesis.

Nevertheless, Paige's anti-Marxian conclusion must be taken with a grain of salt. The antirevolutionary hero of Paige's drama is the modern plantation whose progressive technology allows a constantly expanding standard of living. For Paige, revolution is as obsolete in third world agriculture as in modern industry. Reading this sort of conclusion requires an act of faith at a time when modern industry is beset with fundamental problems, not the least of which is the uncertain future exploitation of export economies such as Paige describes.

Paige himself hints at the struggles within export agriculture in the third world. Profits from W. R. Grace's sugar in Peru no longer depend upon its sugar plantations; control of refining marketing gives it every bit as much power as before land reform (p. 142). United Fruits's retreat from production is also recognized. With multinational corporations replacing the traditional landowning elite as the source of exploitation, new forms of political struggle must develop. The paucity of "events" by wage workers on the plantation may just as well mean a temporary pause to develop new tactics as a final outcome in the "calculus of force."

Agricultural economists will certainly benefit from the descriptive sections of the book, especially his treatment of the enormous institutional variations that come in the wake of market fluctuations. Finally, the book develops a valuable picture of how development as well as its absence affects the lives of the working people who grow the export crops in the third world.

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Prescott, James R., and W. Cris Lewis. *Urban-Regional Economic Growth and Policy*. Ann Arbor: Ann Arbor Science Publishers, 1975, x + 220 pp., $12.50.

As stated in the preface, this book deals with numerous problems along the size continuum of subnational regions and issues of policy at the local, state, and national levels. The principal objective is to analyze some of the major difficulties encountered at each spatial level and to suggest how various methods may be used to empirically estimate their impacts.

The book reports on several empirical studies conducted by the authors in the midwestern United States. The book is easy to read; there are several equations, but they are empirical rather than theoretical derivations. The book assumes a basic knowledge of econometric modeling, simulation modeling, discriminant analysis, linear programming, and regression analysis. This book should be of interest to agricultural economists because of its implications for rural development policies and for the research techniques applied to problems in rural-urban regions.

Chapter 1 introduces concepts useful in understanding the subsequent chapters. It contains very brief discussions of bid-rent location theory, export base theory, and central place theory. These discussions are too brief to be useful, and their relevance to the rest of the book is not explained. There is a better discussion of spatial delineation, including political policy regionalization, further on.

Trends in rural development and policy are related to the concepts of central place theory in the next chapter. The discussion of the relationship between rural development and the export base theory is weak; there is no discussion at all relating it to bid-rent theory. There is a good discussion of

four specific rural development policies, but the reader is left wondering if perhaps there may be other alternatives. The chapter relates specifically to two substate regions in Iowa; the explanation of their position in the central place theory hierarchy could be improved.

Chapter 3 describes an econometric model relating population and employment levels in central and peripheral counties to other socioeconomic variables. The explanation of the correlation between variables, both dependent and independent, is good. However, many of the independent variables appear questionable based on the significance of their *t*-values. These variables remain in the econometric equations with little or no explanation. The empirical results generally confirm the advantages to both firms and households of central locations. The analysis of the policy implications flowing from the model is weak, and there is little discussion of the relevance of empirical results to the central place and export base theories introduced in chapter 1.

A brief discussion of water resource development begins chapter 4, but the chapter is concerned mostly with the development of an interregional linear programming model of agricultural commodity flows. Most of the data used is obsolete, given the tremendous changes occurring in the domestic and foreign agricultural situation in the early 1970s. Again, empirical results are not adequately related to rural development policies or to the basic theories underlying the whole book.

Chapter 5 includes a description of a simulation model of the Des Moines, Iowa, labor market area. The model contains demographic (cohort-survival), employment (participation rates and productivity coefficients), output (input-output), final demand (location quotients), and capital (coefficient matrix) equations. The assumptions and basic results of the model are described. There is no discussion, however, of the obvious rural development policies suggested by the model. The chapter also contains a detailed description of an interurban earnings differential model. Development and results of several regression analyses are discussed, but again there is little regional development policy analysis.

In chapter 6 is a detailed discussion of a model used to evaluate the incidence of an Iowa veterans allowance tax. There is a good discussion of the incidence of the tax and of policy alternatives for correcting inequalities, both on the tax payers and the receiving units, as well as of the development of and results from use of discriminant analysis to evaluate four state and local industrial location incentive programs. This chapter is quite empirically oriented and should be of interest to researchers evaluating the incidence and effect of taxation and industrial location policies. Improvements could have been made by relating the empirical results to the central place, export base, and bid-rent theories introduced earlier. The most important conclusion reached in this chapter is that politics, not economics, has been the more important consideration in determining the distribution of incentive programs.

The seventh chapter contains a nontechnical discussion of the proposed Minnesota Experimental City including development problems and direct and indirect goals. There is also a nontechnical discussion of redevelopment problems associated with small urban communities, new towns, and other smaller scale projects. There is a discussion of optimal city size relating it to central place and export base theory.

In the last chapter the empirical and policy results of the previous chapters are summarized. An attempt is made to integrate empirical results, central place and export base theory, and policy implications.

To conclude, the book introduces central place, export base, and bid-rent theory and then attempts to integrate several empirical results with this theory and to discuss rural development policy alternatives. The theories, however, are too briefly introduced and then never adequately related to most of the empirical results. Empirical results, in turn, are not adequately related to policy implications. The result is a presentation of several empirical analyses that are not adequately related to regional growth and policy, as the title of the book suggests.

John W. Green
Economic Research Service
U.S. Department of Agriculture

Reynolds, Lloyd G., ed. *Agriculture in Development Theory*. New Haven: Yale University Press, 1975, x + 510 pp., $25.00.

This is not really a book about the role of agriculture in development theory, as the title suggests. Rather, it is a collection of interesting papers about various aspects of peasant behavior and agricultural development that are relevant to the formulation of theories of economic development. The characteristics of the agricultural sector dealt with in the volume are not explicitly linked to any development theories.

The book contains fifteen papers in addition to the introductory chapter by Lloyd Reynolds, "Agriculture in Development Theory: An Overview." Three of the papers deal with the economics of peasant production, two with the behavior of peasants under alternative tenure systems, three with the generation and diffusion of new agricultural technology, two with agricultural sector performance, three with agriculture, growth, and trade, and two with agricultural development under different economic systems. Some of the papers are purely theoretical, some combine theory with empirical investigation, and some are descriptive in nature. The basic content of several papers has

appeared in other publications, e.g., those by Ruttan, Evenson, and Timmer and Falcon.

I found several of the papers to be especially interesting. The one by Hla Myint, "Agriculture and Economic Development in the Open Economy," deals with the functions agriculture can perform in the process of economic development, i.e., increasing the domestic supply of food and releasing labor for industrial employment, enlarging the size of the domestic market for the manufacturing sector, increasing the supply of savings, and providing foreign exchange earned by agricultural exports. He discusses the degree of compatibility among policies designed to promote these functions of the agricultural sector, including the conflict inherent in providing production incentives to farmers and increasing agriculture's contribution to domestic savings.

Raj Krishna's paper deals with measuring the direct and indirect employment effects of agricultural growth with technical change. He attempts to redress the imbalance in the literature that deals primarily with the direct employment effects of technical change. Krishna shows that the indirect effects on employment may be substantial but not always enough to offset the decline in employment in agricultural production that might result from technical change.

Gerald Helleiner's paper, "Smallholder Decision Making: Tropical African Evidence," is a good review of the literature on peasant behavior in Africa. I agree with Helleiner's contention that "research results from the African continent are not adequately represented in many of the existing general analyses of agricultural development" (p. 27). He provides a good systematic review of the literature dealing with peasant behavior in Africa.

Those interested in agricultural development and its relationship to economic development will find this volume to be a useful reference. It contains material on a wide variety of topics. Each individual will have to decide whether or not there is enough material of interest to warrant the price.

Martin E. Abel
University of Minnesota

Books Received

Abdel-Fadil, Mahmoud. *Development, Income Distribution and Social Change in Rural Egypt: A Study in the Political Economy of Agrarian Transition.* New York: Cambridge University Press, 1975, xiii + 157 pp., $15.50, $7.95 paper.

Aresvik, Oddvar. *The Agricultural Development of Jordan.* New York: Praeger Publishers, 1976, xxviii + 375 pp., price unknown.

Barth, Alan. *Rights In Conflict.* New York: McGraw-Hill Book Co., 1976, ix + 112 pp., price unknown.

Committee on Economics Teaching Material for Asian Universities. *Economic Theory and Practice in The Asian Setting.* Vol. 1. Macroeconomics. Vol. 2. Microeconomics. Vol. 3. The Economics of Agriculture. Vol. 4. The Economics of Development. New Delhi, India: Wiley Eastern Limited, 1975, Rs. 24:00.

Delucchi, V. L. *Studies in Biological Control.* New York: Cambridge University Press, 1976, xvi + 304 pp., $34.50.

Eckstein, Shlomo, Avraham Sharon, and **Benjamin Ilan.** *Intervillage Cooperation in Agricultural Production Services.* Jerusalem, Israel: Keterpress Enterprises, 1974, 218 pp., price unknown.

Fallenbuchl, Zbigniew M. *Economic Development in the Soviet Union and Eastern Europe, Volume 2.* New York: Praeger Publishers, 1976, xvii + 409 pp., $27.50.

Heady, Earl O., and **Larry R. Whiting.** *Externalities in the Transformation of Agriculture: Distribution of Benefits and Costs from Development.* Ames: Iowa State Press, 1975, viii + 341 pp., $11.50.

Holloway, Thomas H. *The Brazilian Coffee Valorization.* Wisconsin: Department of History, University of Wisconsin, 1975, viii + 112 pp., $8.50.

Kampp, Aa. H. *An Agricultural Geography of Denmark.* Budapest, Hungary: Akademiai Kiado, 1975, 88 pp., $5.50.

Kearl, Bryant. *Field Data Collection In The Social Sciences: Experiences in Africa and the Middle East.* New York: Agricultural Development Council, 1976, xxiv + 200 pp., price unknown.

Lockner, Allyn O., and **B. J. McCandless.** *Provisional Models for Developing an Undergraduate Economics Program.* Pierre, S. Dak.: State Publishing Co., 1975, 20 pp., $1.25.

Magee, Stephen P. *International Trade and Distortions in Factor Markets.* New York: Marcel Dekker, 1976, vi + 140 pp., $16.50.

Matz, Samuel A. *Snack Food Technology.* Westport, Conn.: AVI Publishing Company, 1976, vii + 349 pp., $29.00.

Mellor, John W. *The New Economics of Growth: A Strategy For India and the Developing World.* Ithaca, N.Y.: Cornell University Press, 1976, xv + 335 pp., $11.50.

Mikdashi, Zuhayr. *The International Politics of Natural Resources.* Ithaca, N.Y.: Cornell University Press, 1976, 214 pp., $12.50.

Mikes, Richard J., and **Douglas C. Braithwaite.** *Managing Rural Change: Economic Growth In The Southeast.* Athens: University of Georgia Printing Department, 123 pp., price unknown.

Nickerson, John T. R., and **Louis J. Ronsivalli.** *Elementary Food Science.* Westport, Conn.: AVI Publishing Co., 1976, viii + 368 pp., $25.00, $13.00 paper.

Phillips, W. E. *The Conservation of the California Tule Elk: A Socioeconomic Study of a Survival Problem.* Canada: University of Alberta Press, 1976, 120 pp., $4.00.

Pyenson, Louis L., and **Harvey E. Barke.** *Laboratory Manual for Entomology and Plant Pathology.* Westport, Conn.: AVI Publishing Co., 1976, vi + 122 pp., $8.00.

Reserve Bank of India. *The Small Farmers Development Agencies (1972–73): A Field Study.* Bombay, India: Reserve Bank of India, 1975, xi + 214 pp., price unknown.

Roth, L. O., F. R. Crow, and **G. W. A. Mahoney.** *An Introduction To Agricultural Engineering.* Westport, Conn.: AVI Publishing Co., 1975, ix + 356 pp., $32.00, $15.00 paper.

Schapsmeier, Edward L., and **Frederick H. Schapsmeier.** *Encyclopedia of American Agricultural History.* Connecticut: Greenwood Press, 1975, xii + 467 pp., $25.00.

Scrimshaw, Nevin S., Daniel I. C. Wang, and **Max Milner.** *Protein Resources and Technology: Status and Research Needs Research Recommendations and Summary.* Cambridge: Department of Nutrition and Food Science, Massachusetts Institute of Technology, 1975, x + 100 pp., price unknown.

Tennessee Valley Authority. *Quality Housing Environment for Rural Low-Income Families.* Muscle Shoals, Alabama: Tennessee Valley Authority, 1975, 124 pp., price unknown.

Thorner, Marvin Edward, and **Peter Burnam Manning.** *Quality Control in Food Service.* Westport, Conn.: AVI Publishing Co., 1976, vii + 368 pp., $25.00, $13.00 paper.

Whyte, Robert Orr. *Land and Land Appraisal.* The Hague, Netherlands: Dr. W. Junk b. v. Publishers, 1976, xiv + 370 pp., price unknown.

Williams, C. N. *The Agronomy of the Major Tropi-*

cal Crops. New York: Oxford University Press, 1975, xix + 228 pp., $21.50.

Yotopoulos, Pan A., and **Jeffrey B. Nugent.** *Economics of Development: Empirical Investigations*. New York: Harper and Row Publishers, 1976, xxiii + 478 pp., price unknown.

News

Announcements

1976 Meeting Allied Social Sciences Association

The American Agricultural Economics Association will meet jointly with the Allied Social Sciences Association in Atlantic City, New Jersey, 16–18 September 1976. Sessions are being scheduled as follows: (*a*) Food and Agricultural Policy Issues: Round Table Discussion; James Shaffer, Michigan State University, moderator, (*b*) Sources and Effects of Instability in U.S. Agriculture: Recent Experiences; Jimmye Hillman, University of Arizona, chairman, (*c*) Economics of Consumption: Conceptual and Empirical Developments; Rueben Buse, University of Minnesota, chairman, and (*d*) Econometric Modeling of the Agricultural and General Economic Sectors. Program details are available from Kenneth R. Farrell, President-Elect, AAEA, Economic Research Service, U.S. Department of Agriculture, Washington, D.C. 20250.

The American Library Association's Biennial Oberly Memorial Award

The Eunice Rockwell Oberly Memorial Award, consisting of a citation and a cash award, is made to the American citizen who compiles the best bibliography in the field of agriculture or one of the closely related sciences in the two-year period preceding the year in which the award is made. This award has been presented biennially since 1925. The 1977 award will be presented during the annual conference of the American Library Association, June 1977. Deadline for nominations is 15 March 1977. Nominations are to be sent to Mr. David K. Oyler, Chairperson, Oberly Memorial Award Committee, Steenbock Memorial Library, University of Wisconsin, 550 Babcock Drive, Madison, Wisconsin 53706.

New Journal

State and Local Government Review is a triannual publication of the Institute of Government, University of Georgia, devoted to research dealing with the practical problems of state and local government. As a multidisciplinary journal, the *Review* welcomes all articles concerning applied research, university-based public service programs and training, policy making and implementation, and programs in state and local government. Our preference is for manuscripts that would appeal to practioners and to academics. Short- to medium-length articles (11–20 typewritten, double-spaced pages) and notes (10 pages or less) are desired, but longer manuscripts will be considered. For further information, write to Dr. David Billings, Editor, Terrell Hall, University of Georgia, Athens, Georgia 30602. A one-year subscription is $6.00.

Personnel

University of Arizona

Resignation: Paul N. Wilson, former instructor, is with the Agency for International Development, Washington.

Colorado State University

Returns: Huntley H. Biggs is back after a two-year assignment as a development economist for Development and Resource Corporation, Sacramento, working with Iran's Ministry of Water and Power in formulating a national water plan; **Donald M. Sorensen** is back after a two-year assignment as acting assistant director of the Western Rural Development Center, Oregon State University; **Ronald L. Tinnermeier** is back from a two-year special assignment with the Agency for International Development and the USDA Technical Assistance Bureau.

Cornell University

Resignation: Dennis R. Lifferth, former assistant professor of business management, is an agricultural economist for the Welfare Services' Production-Distribution Department of the Church of Jesus Christ of Latter-Day Saints.
Honor: Robert S. Smith, professor of farm finance, received the Superior Performance Award from Lambda Chapter of Epsilon Sigma Pi, the honorary extension fraternity, for his teaching and leadership in the field of farm family financial management and agricultural credit.

University of Florida

Appointment: Lester H. Myers is the director of the Economic Research Division, Florida Department of Citrus.
Leave: John Holt is a visiting professor, Extension Service—USDA, Oklahoma State University, and is working on a project dealing with wheat farm management in an environment of risk and uncertainty.
Resignation: Lawrence A. Halsey is the county extension director of Jefferson County, Monticello.

CED: Commodity Economics Division of the Economic Research Service, USDA; **NEAD:** National Economic Analysis Division of ERS.

University of Georgia

Resignation: Richard J. Mikes, former associate professor of agricultural economics, is an assistant controller, Ruan Transport Corporation, Des Moines, Iowa.

University of Illinois

Appointments: Darrel L. Good, former assistant professor of farm management, Cornell University, is an assistant professor of marketing; **Keith M. Naber,** M.S. Purdue University, is a Farm Business Farm Management fieldman.
Leaves: J. S. Gruebele and **S. C. Schmidt** are on sabbatical leave for one year; **J. C. van Es** is on sabbatical leave for six months.

University of Maryland

Appointments: Norman Bender is a marine extension specialist in the Department of Agricultural and Resource Economics; **Ying-Nan Lin,** Ph.D. University of Tennessee, is an assistant professor.

Michigan State University

Appointment: George Axinn is in Nepal for two years; **Michael Weber** is the agricultural economics advisor to the Michigan State University Brazil Project, University of Ceara, for two years.
Leave: Larry Connor is in the East Lansing area for six months of studying and writing.
Return: Alan Thodey is back after working in Korea.
Resignation: William Haley, former assistant professor, is self-employed.

University of Nebraska

Appointment: Lynn Lutgen, Ph.D. University of Nebraska, is an assistant professor of livestock marketing economics.
Return: Loyd K. Fischer, professor of agricultural economics, is back after serving as a visiting professor of agricultural economics, University of Missouri.
Retirement: A. W. Epp, former professor of agricultural economics, has left after thirty-three years of service.
Honor: A. W. Epp received a Distinguished Service Award from the Nebraska Society of Farm Managers and Rural Appraisers.

University of Nevada

Appointment: Gordon Myer, Ph.D. University of Missouri, is with the Division of Agricultural and Resource Economics.
Retirement: Doyle Spurlock, former public affairs specialist, Federal Extension Service, Washington, and visiting professor, fall 1975, is in Arizona.

New Mexico State University

Appointment: Robert O. Coppedge is a community development specialist in the Extension Service.

North Carolina State University

Appointments: Thomas M. Reynolds and **Grant M. Scobie** are assistant professors of economics and business.

Oklahoma State University

Appointments: John E. Ikerd, Ph.D. University of Minnesota, is an extension economist in livestock marketing; **James N. Trapp,** formerly with Michigan State University, is an assistant professor in the area of commercial agricultural economics.

Oregon State University

Appointment: Ronald A. Oliveira, formerly with the University of Wisconsin, is an assistant professor of agricultural and resource economics.

Stanford University

Appointment: Anne E. Peck, former assistant professor, Purdue University, is an assistant professor at the Food Research Institute.

University of Tennessee

Appointment: Rodney Thomsen, Ph.D. University of Tennessee, is an assistant professor of agricultural economics.

U.S. Department of Agriculture

Appointments: Tim Baker, Economic Research Service, is an adjunct instructor at Michigan State University; **John Connor,** Ph.D. University of Wisconsin-Madison, is with NEAD, Madison, Wisconsin; **Don Ethridge** and **Dale Shaw,** CED, are adjunct professors of agricultural economics at Texas Tech University; **Thomas Lederer,** Ph.D. University of Tennessee, is with the Economic Research Service.

University of Vermont

Resignation: Arthur H. Smith, former assistant professor, is the full-time manager of his own business.

Virginia Polytechnic Institute and State University

Appointment: Steven T. Buccola, Ph.D. University of California, Davis, is an assistant professor.

University of Wisconsin

Appointment: Neil Meyer, area community development agent, Minnesota, is an assistant extension professor and extension community resource development specialist.

Other Appointments

Alvin A. Bedel, Ph.D. University of Tennessee, is with the School of the Ozarks, Point Lookout, Missouri.
Robert Burney, M.S. University of Tennessee, is with Central Soya, Fort Wayne, Indiana.
Samuel T. Cooper, Ph.D. University of Tennessee, is a cooperative extension agent—Manpower, Operation Hitchhike, New York Cooperative Extension Service, Cobleskill.
Khairulah Dawlaty, Ph.D. University of Tennessee, is at the University of Kabul, Afghanistan.
Leonardo Gonzales, Ph.D. University of Tennessee, is with the ADAM Project, Bureau of Agricultural Economics, Quezon City, Philippines.
Morgan Gray, M.S. University of Tennessee, is an analyst in corporation planning and economic research, Goldkist Cooperative, Atlanta, Georgia.
Francisco Samuel Hosken, M.S. Purdue University, is the department head of the Brazilian Cheese Manufacturing Co., Governador Valadares.
John B. Huie is the director of the State Budget Agency, Indiana.
Morris T. Jones, Ph.D. University of Tennessee, is an assistant professor of economics at Baptist College, Mobile, Alabama.
Pham Kham, M.S. University of Tennessee, is with the Economist Outreach Division, International Fertilizer Development Institute, Florence, Alabama.
Alfredo Sfeir-Younis, Ph.D. University of Wisconsin-Madison, is in the Young Professional Program, International Bank for Reconstruction and Development, Washington.
Raymond W. Waldron, M.S. Oregon State University, is with the Ministry of Natural Resources, Government of Honduras.

Obituary

Robert E. Post

Robert E. Post passed away on 6 March 1976 after a long illness. Bob was a lifelong member of the American Agricultural Economics Association and worked with many association members over the years. He authored the *Wheat Situation* report for the U.S. Department of Agriculture from the 1930s until his retirement in 1962.

Post was born in Minnesota in 1896 and earned a B.S. at Michigan State University and an M.S. at the University of Wisconsin. Prior to joining the Department, Bob taught economics for a number of years at South Dakota State University. After joining the USDA, he was a delegate to the first conference to establish an International Wheat Agreement, which took place in London during the summer of 1939. Later assignments involved wartime food planning and analysis of legislative and economic proposals.

Post is survived by his wife, Norine, daughter, Mrs. James Rimmer, and three grandchildren.

RESEARCH DIRECTOR FOR FOREST ECONOMICS AND POLICY

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University of Minnesota Press

Just published—an invaluable reference work, an excellent book for course use

American Farm Policy, 1948-1973

by **Willard W. Cochrane** and **Mary E. Ryan**

This comprehensive account records and explains American farm policies and programs in the last quarter-century and provides a background and analysis as well. The authors describe in detail the farm policy legislation during the period and the operations of the programs in those years. The program data are derived largely from materials published by the U.S. Department of Agriculture which are now difficult to obtain. The organization of the data into extensive tables makes the work particularly valuable for reference. Since Dr. Cochrane, the senior author, was deeply involved with the farm programs of this period as a critic, analyst, and planner, he has a unique vantage point for the interpretation and appraisal of the policies.

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11. **Review by colleagues.** Authors are strongly urged to have their manuscripts critically reviewed by their colleagues prior to submission.
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15 JUL 1977

American Agricultural Economics Association

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Objective

The AAEA seeks to further the systematic development of knowledge of agricultural economics in order to improve agriculture and agriculture's contribution to the general economy. The activities of the AAEA include:

—publishing the *American Journal of Agricultural Economics;*
—planning and conducting two annual meetings of the membership;
—sponsoring annual awards for outstanding extension programs, distinguished teaching, and outstanding research;
—recognizing outstanding agricultural economists through a fellows program;
—supporting a literature retrieval system in cooperation with the U.S. Department of Agriculture;
—publishing periodically a biographical directory of the AAEA's members;
—supporting an employment registry for agricultural economists in cooperation with the U.S. Department of Labor.

Membership and Subscriptions

Membership in the AAEA is open to individuals having a professional interest in agricultural economics. Dues, payable at the beginning of each calendar year, are as follows: regular members, $25, senior members, $12.50, and junior members, $12.50. Senior membership is open to persons, upon written request, who are sixty-five years of age or older and have retired from active professional work. Junior membership is for students and is limited to three years; students should use application forms available from and signed by the head of the department in which they are studying: Members receive this *Journal*.

The subscription rate for institutions and nonmembers is $35 per year. Individual issues of this *Journal* are $10.00.

Payment of membership dues, correspondence regarding subscriptions, orders for individual copies of the *Journal*, changes in address, or inquiries about the general affairs of the AAEA should be sent to John C. Redman, Secretary-Treasurer, American Agricultural Economics Association, Department of Agricultural Economics, University of Kentucky, Lexington, Kentucky, 40506.

American Journal of Agricultural Economics

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November 1976 Part I

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Price Support versus Input Subsidy for Food Self-Sufficiency in Developing Countries

Randolph Barker and Yujiro Hayami

Self-sufficiency in food grains has been a publicized goal of government policy in many developing countries. Among various alternatives to achieve this goal, two policy options, output price support and input subsidy, both characterized by the government intervention into market pricing, are evaluated by applying a simple demand-supply model to the Philippine rice economy. The results demonstrate a possibility that a subsidy applied to modern inputs, such as fertilizer, that are being used below optimum can be more beneficial than supporting product prices.

Key words: fertilizer subsidy, food self-sufficiency, foreign exchange, government cost, net social welfare, rice price support.

Many of the nations in South and Southeast Asia that gained independence after World War II have adopted self-sufficiency of food staples as a national policy goal. These countries, whose economies were based on the export of tropical cash crops under colonial rule, have chosen this policy of self-sufficiency in the nationalistic desire to minimize foreign power leverages, and in order to reduce foreign exchange requirements for the import of foodstuffs.

The food self-sufficiency goal can be achieved best, in the long run, through the improvement in physical and institutional infrastructure such as irrigation and research-extension systems, which have the main effects of shifting production functions. However, because such programs require extremely large investments and long gestation periods, there is always a temptation for government to adopt shorter run policies, such as supporting product prices and subsidizing inputs, thus stimulating farm producers to increase food output along existing production functions. The temptation becomes stronger during periods of occasional food shortage and high prices.

Assuming an economy is operating with a high degree of competition in factor and product markets, government interventions in the pricing of products and inputs will invariably result in a net loss in the economic welfare of society. However, ample evidence is available that the level of modern inputs such as fertilizer is much lower than the optimal level (marginal value product equal to marginal cost) due to lack of knowledge, risk aversion, and other reasons. Assuming a large gap between actual and optimum levels in the input of fertilizer, it is possible that the subsidy on fertilizer, which stimulates increase in its application, may result in a net welfare gain to the society. The support of product prices is likely to require more social cost than benefit because, in addition to increasing fertilizer, it will induce the use of traditional inputs such as land and labor above their economic optimum.

In this paper, we attempt to illustrate the effects of such policies by analyzing the programs of rice price support and fertilizer subsidy for achieving self-sufficiency in rice in the Philippines. Benefits and costs associated with these alternative programs and their income distribution effects are estimated and compared with the case of no support or subsidy. Based on the results of estimation, we discuss advantages and disadvantages of these policy

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alternatives in terms of efficiency and equity criteria.

First, we review the history of rice and fertilizer price policies in the Philippines in order to identify policy goals and constraints in achieving rice self-sufficiency. Second, we develop a model of estimating benefits and costs associated with alternative policy programs. The results of estimation are compared with the actual choice of programs in order to make inference on the motivation and the decision criteria of policy makers.

Goals and Constraints of Rice Policy

Despite the publicized goal of national self-sufficiency, over the past two decades the Philippines has been the second largest importer of rice in Southeast Asia, second only to Indonesia. The Philippine government has operated a price-policy program for rice designed to support a floor price for producers and maintain a ceiling price for consumers. Although a major justification for such a program has been the protection of the income of small farmers, as Mangahas has pointed out, this policy has been biased more in favor of consumers than producers. Considering the critical importance of rice as a wage good, it seems reasonable to assume that the overriding restraint faced by the government in designing a rice policy to achieve self-sufficiency has been the necessity of supplying rice to urban consumers at relatively low prices.

There is, of course, a gap between the price considered appropriate for consumers (consumer ceiling) and the price needed to insure self-sufficiency (farm floor). The Philippine government has never purchased more than about 5% of the domestic rice crop, and as a result the government cannot maintain a margin between the floor price for producers and the ceiling price for consumers much in excess of the normal marketing margin. Given the limitations of the government budget and the desire to supply cheap rice to consumers, it has been difficult to raise the producer price support to the level required to achieve self-sufficiency.

Instead, the government has used its limited resources to import rice when it appeared that the rice price would rise well above the consumer ceiling, especially in election years. Normally, the Philippine and world rice prices are fairly similar. Hence, this policy produces very little drain on government resources. In years of world rice shortage (e.g., 1967 and 1973), the international price rises well above the domestic price and importation is costly. But the basic requirement to supply rice at reasonably low prices has not prevented the government from restricting rice imports in those years when the prices for imported rice are very low (1969–70).

Another policy instrument used by the Philippine government to encourage rice self-sufficiency has been the subsidy on inputs for rice production, especially fertilizer. Over a seven-year period from 1956–57 to 1962–63, the government-supported farmers' cooperatives purchased and distributed fertilizer to rice and corn producers at half the going market price. The recent "world food crisis" and the dramatic rise in fertilizer prices in 1973 triggered by the oil embargo of the Arab nations has once again induced the government to adopt a program designed to subsidize the use of fertilizers. As world fertilizer prices began to rise in 1972, the government assumed control of pricing in the fertilizer industry and initiated a "socialized pricing" program. Despite the four-fold increase in import prices of fertilizer, the price to rice growers was allowed to increase only two-fold, resulting in a subsidy of about 100% in 1974.

A major problem with the fertilizer subsidy as a means of increasing rice production has been the difficulty of limiting the subsidy to the rice sector, that is, preventing the diversion of subsidized fertilizers to the export crop (especially sugar) sectors. In spite of vigorous enforcements under the Martial Law, the diversion became so large that in November 1974, the government was compelled to reduce the rate of fertilizer subsidy for rice producers in order to narrow the gap in fertilizer prices between the rice and the sugar sectors. Subsequently, the reformulation of rice and fertilizer price policies has become a critical agendum.

Model of Policy Evaluation

In this section, we develop a model for estimating the benefits and costs associated with four alternatives for achieving self-sufficiency in rice production. These alternatives include a rice price-support and three fertilizer-subsidy plans—plan A with a subsidy for rice

producers only, involving a two-price system for fertilizer; plan B with a subsidy price for fertilizer the same for all crops; and plan C, the same as plan B but financed in part by an increase in the sugar export tax lessening somewhat the benefits to the sugar sector. Simplifying assumptions adopted for the analysis follow.

First, we assume that none of producers and consumers are large enough to influence market prices; thereby unique schedules can be specified for domestic supply and demand. Second, we assume that a change in fertilizer prices does not significantly affect the use of other inputs.[1] Third, only the rice and sugar sectors that account for over 80% of the total fertilizer consumption are considered, and interactions with other food crops (such as corn) and export crops (such as coconuts) are abstracted from the analysis. The sugar sector includes both sugar planters and millers.[2] Finally, we abstract from the analysis the changes in marketing costs that might be involved with the adoption of rice price-support or a fertilizer-subsidy program.[3]

A simple model of rice price support and fertilizer subsidy in the Philippines is presented in figure 1. SS represents the domestic supply curve for rice.[4] The vertical line D_hH represents the demand curve of producers for home consumption. Here it is assumed that producers' households consume the same quantity of their produce irrespective of prices and sell the rest in the market. (For the support of this assumption, see Toquero et al.) D_mD represents the market demand for the product—the horizontal distance between D_mD and D_hH measures the quantity purchased by urban (nonfarmer) households. The total demand for rice is represented by D_hD_mD.

Normally, the world price of rice (OP_w) has been below the domestic equilibrium price (OP_e) that would have been established at the intersection of D_mD and SS. Without government intervention the Philippines would import AB. Assume first that the price for imported rice is exactly equal to a target price (OP_d) for domestic consumers that the government intends to maintain. If OP_d is the domestic target price, then it will be necessary to have OQ_c available for consumers. There are three possible alternatives: (*a*) import AB, (*b*) support the rice price received by producers at OP_s, or (*c*) subsidize fertilizer prices sufficiently to shift the supply function from S to S'.

The first alternative, which has been the traditional policy of the Philippine government, serves as a standard of comparison for the alternative self-sufficiency policies represented by the price support of rice and price subsidization of fertilizer.[5]

A slight variation of the initial assumption is shown also in figure 1. The world price may be either below the target retail prices ($OP'_w < OP_d$) or above the domestic target retail price ($OP''_w > OP_d$). If the government maintains imports at AB, it will incur a profit in the former case by restricting imports and selling above the purchase price (OP'_w). This policy will protect domestic producers and earn revenue for the government at a cost to the consumer. However, in the latter case when the world price is above the domestic sale price, the import required by the government to maintain the domestic price at OP_d is greater than would occur under free trade. Selling below the purchase or import price benefits the consumers at a cost to the government and the producer. Due to the fluctuation in the world price relative to the domestic target (OP_d), the Philippines in the recent past has

[1] This assumption implies zero cross elasticity in input demand functions. To the extent that fertilizer is a substitute for or complementary with other inputs, especially land, the results of our analysis are biased. Fertilizer is a substitute for land itself, but it has a strong complementarity with irrigation systems that improve land quality. These competitive and complementary relations are highly complex so that it is difficult to identify the direction of the possible bias.

[2] The different effects of price policies on sugar planters and millers is an interesting subject particularly in the Philippines where these two groups operate very independently of one another. However, because of the complexity and data limitation, planters and millers are not identified separately in this analysis.

[3] This is partly because of data limitation and partly because there are many options to administer the same program. For example, price support in buying rice from producers at higher prices and selling to consumers at lower prices can be administered either through the establishment of a government marketing agency or through subsidizing private marketing firms. Distribution of benefits and costs between the government and the private sector differs for different administrative designs.

[4] The supply response in the Philippines has been primarily based on the response in the use of traditional inputs such as land and labor. Previous studies of rice supply by Mangahas, Recto, and Ruttan indicate that the price response of supply is largely an area response effect. It is reasonable to assume that area response accompanies a more or less parallel change in labor. Thus, in the case of the Philippines, the production cost represented by an area below SS consists primarily of the opportunity costs of land and labor.

[5] It is important to note that our standard of comparison is different from the free market equilibrium, which is usually used as a benchmark of price policy evaluations (e.g., Johnson, Wallace). Our benchmark assumes governmental intervention in the control of rice import in order to ensure a target rice price for consumers. Our benchmark coincides with the free market equilibrium when the target price is the same as the world price.

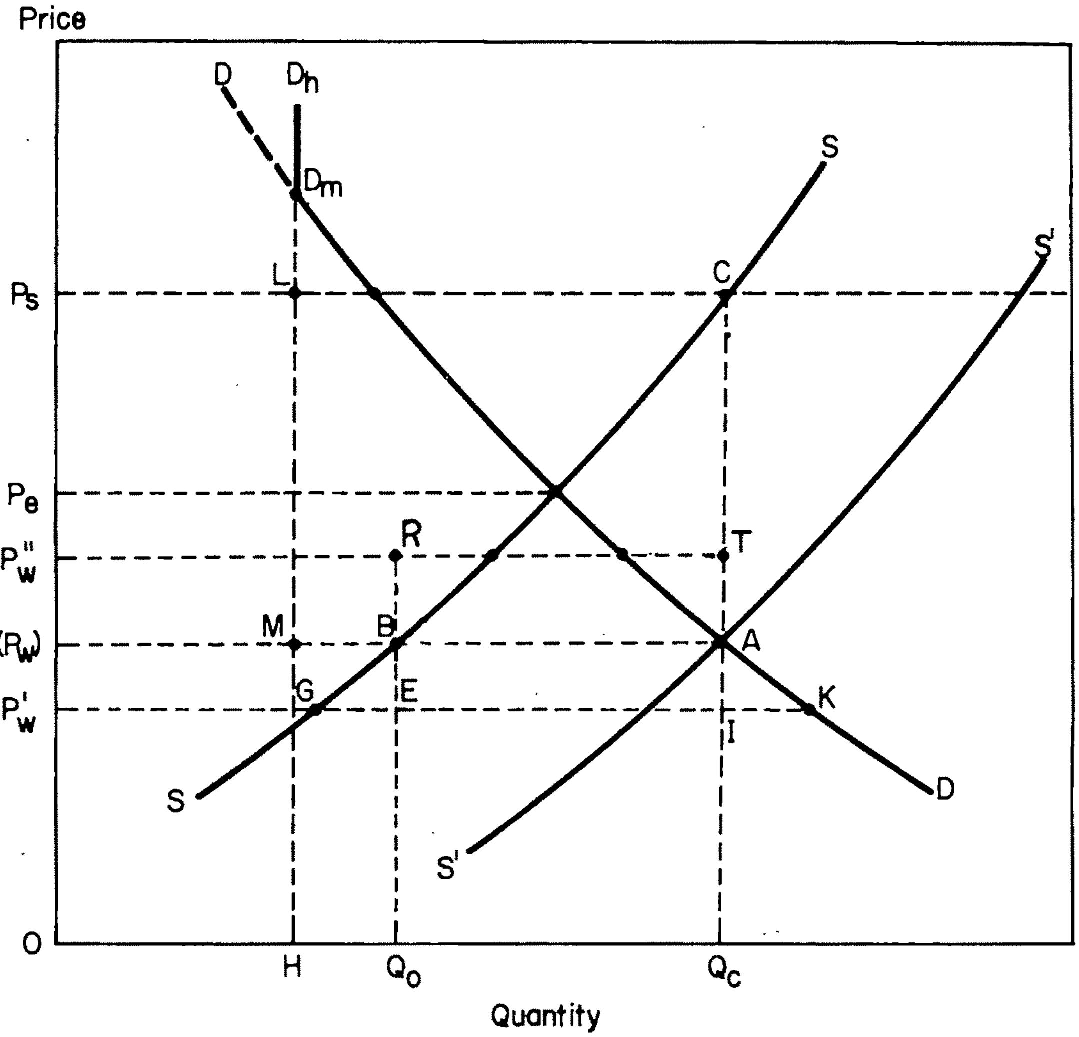

Figure 1. Model of price support and fertilizer subsidy for rice

profited in some years and lost money in others through its import transactions. On balance, the domestic Philippine price has remained fairly much in line with world rice prices.

Rice Price Support

Assuming a domestic supply schedule (*SS*) as fixed, the self-sufficiency of rice can be achieved by supporting the producer price at OP_s. Since the government has to maintain the consumer price at OP_d, the self-sufficiency of rice by means of price support would involve a cost to the government represented by area *ACLM* as a difference between the procurement cost and the sale.[6] In addition, compared with the check case of importing *AB*, the policy to achieve self-sufficiency by supporting the producer price at OP_s would result in a reduction in government revenues from the import of rice by area *ABEI* if the world price is OP'_w (or an increase by the area *ABRT* if the world price is OP''_w).

With the support price at OP_s, producers' revenue from the sale of rice would increase by area *ACLM*, but the cost of the rice to the producers would also increase by area *ABC*. The difference (area *BCLM*) represents an increase in the income of the rice producers at a cost to the government. The net loss of eco-

[6] If the gap between the producer price and the consumer price is not so large as to cover the marketing cost, producers may retain *OH* for home consumption. However, as the difference becomes larger, producers would sell all of this product and buy back a part for their own consumption. In this case the government cost will exceed area *ACLM* and may even approach to area ACP_sP_d.

nomic welfare to society is represented by the area ABC (aside from the consideration of possible benefits from foreign exchange savings discussed below).

A net savings of foreign exchange is area ABQ_oQ_c (IEQ_oQ_c if world price is lower than domestic price and TRQ_oQ_c if vice versa) minus the increase in fertilizer input due to increased fertilizer application stimulated by a more favorable ratio of fertilizer price to rice price.[7]

Fertilizer Subsidy for Rice

Self-sufficiency of rice can be achieved without supporting the producer price by shifting the supply curve from SS to $S'S'$ in figure 1. Since the supply curve represents a marginal cost curve, it can be shifted to the right by lowering the price of the input.

Given the production elasticity of fertilizer in the rice sector and the price elasticity of demand for fertilizer used for rice production, we can determine the quantity of fertilizer to obtain the increased output needed for self-sufficiency and the decline in price required to induce this additional fertilizer consumption needed.

A model of the fertilizer market is shown in figure 2. The demand curves for the rice (D_rD_r) and sugar (D_sD_s) sectors can be added horizontally to obtain the industry demand curves (DD). The domestic supply curve is SS and the world supply curve (S_w) is assumed to be completely elastic.

If the price of fertilizer applied to rice must be subsidized at OP_{fs} to achieve self-sufficiency, the government cost of fertilizer subsidy to rice is represented by the area $ABP_{fs}P_{fw}$ in figure 2. The reduction (increase) in government revenue due to a decrease in rice imports as a result of the achievement of self-sufficiency (as in the case of rice price support) is represented by the area $ABEI$ (or area $ABRT$) in figure 1.

The rice producers would receive a dual benefit from being able to buy all their fertilizer at a lower cost as represented by the area $CDP_{fs}P_{fw}$ in figure 2 and from the increased output value, area ABQ_oQ_c minus fertilizer cost from using additional amounts of fertilizer because of the more favorable price relationship, area BDX_oX_s in figure 2.

Net savings in foreign exchange can be shown as the net reduction in foreign exchange expenditures for rice imports, area ABQ_oQ_c in figure 1 minus the increase in foreign exchange requirement for increased fertilizer import, area ACX_oX_s in figure 2. As in the case of rice price support, the welfare of rice consumers does not change because they consume the same quantity of rice at the same price irrespective of the support on subsidy programs.

Fertilizer Subsidy for Sugar

We now move to analyze the impact of alternative subsidy plans on the sugar sector. Plan A (two-price system), which charges a market price for fertilizer to sugar growers, involves no additional cost to the government and no change in the income of the sugar sector. Under plans B and C (single-price system), the sugar sector benefits from the purchase of subsidized fertilizers and the government must bear the cost.

The impact of a fertilizer subsidy under plan B is illustrated in figure 3. SS and DD represent respectively domestic supply and demand schedules for sugar. $S'S'$ represents a shift in supply curve corresponding to a fertilizer subsidy for sugar at the same rate as for rice. OR_w is the export price of sugar, whereas OR'_w is the price that sugar producers receive for the export of their product, the difference representing a rate of export tax.

Without the fertilizer subsidy, an equilibrium of sugar production would be established at B with an output OY_o. In this case, if there is no government intervention, export and domestic consumption of sugar would be BJ and JR'_w, respectively. In fact, the Philippine government has been protecting consumers by setting a quota for producers to sell in a domestic market at a lower price (OR_d). Since the consumer price of sugar (OR_d) in figure 3 (similar to the rice price [OP_d] in figure 1) is determined by the government in consideration of social and political stability, it would be maintained irrespective of whether a fertilizer-subsidy program is introduced. Therefore, consumers' welfare with respect to sugar consumption would remain unchanged.

Again referring to figure 2, the government cost of the fertilizer subsidy on sugar as calcu-

[7] It is likely that this formula overestimates the contribution of price support to foreign exchange savings because not only fertilizer import but also the import of other inputs such as farm machineries that have foreign exchange components may be increased as a result of higher rice prices. Also, the export of cash crops such as sugar may be reduced because higher rice prices may result in a diversion of land area from the cash crops to rice.

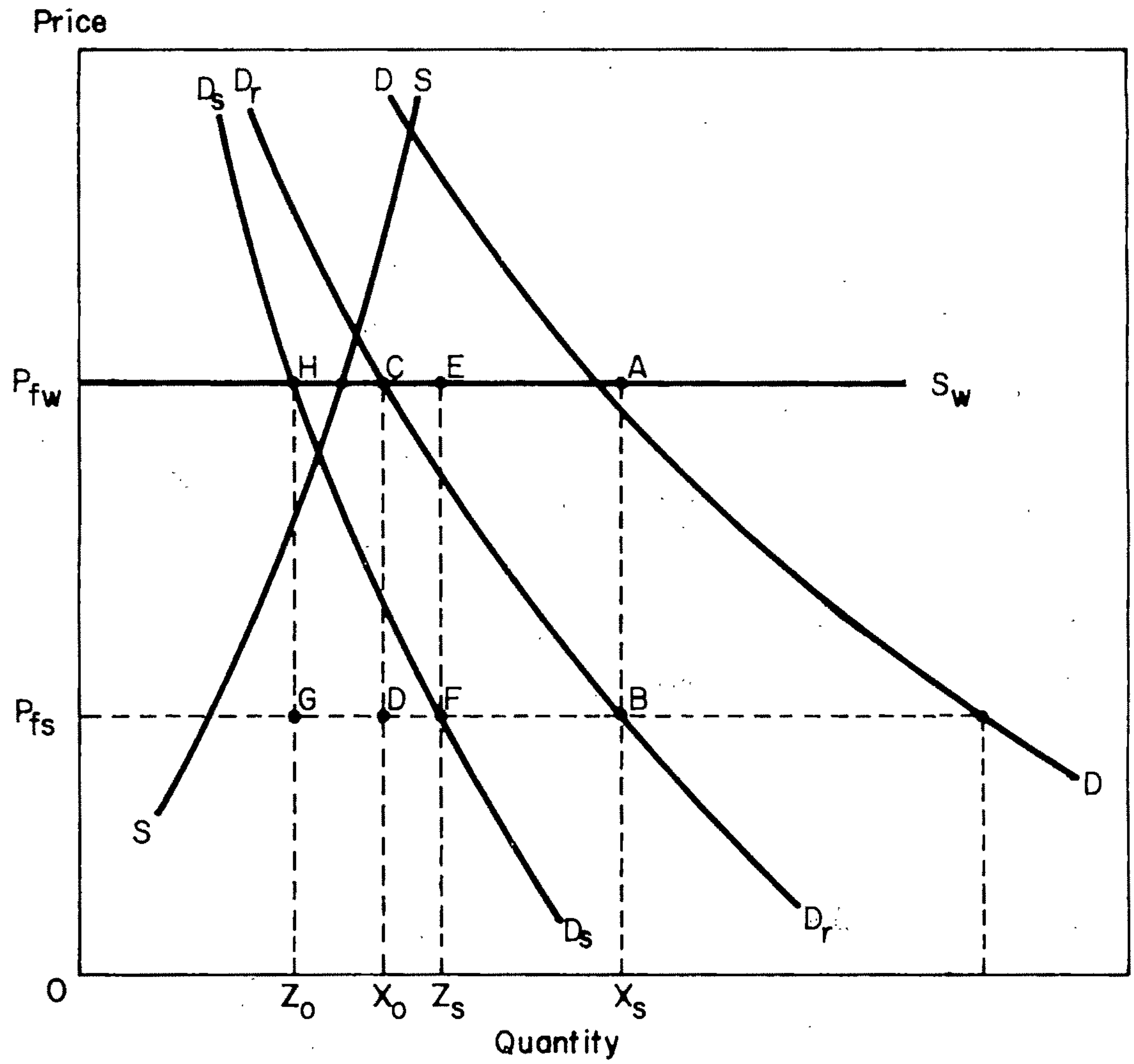

Figure 2. Model of fertilizer demand in relation with subsidy

lated is the area $EFP_{fs}P_{fw}$. Corresponding to the shift in the supply curve from SS to $S'S'$, sugar exports would increase from Y_cY_0 to Y_cY_s (figure 3). Government revenue from sugar export tax would increase by area $BCEH$.

The sugar producers would receive a dual benefit from being able to buy all their fertilizer at a lower cost as represented by the area $HGP_{fs}P_{fw}$ in figure 2 and from the increased output value (area BCY_sY_0 in figure 3) minus fertilizer cost from using an additional amount of fertilizer because of the more favorable price relationship (area FGZ_0Z_s in figure 2).

The net gain in foreign exchange earnings from sugar exports is the area EHY_0Y_s in figure 3 minus the increase in foreign exchange expenditures for fertilizer, area EHZ_0Z_s in figure 2.

If we adopt plan C, which raises the tax rate in sugar corresponding to the magnitude of the fertilizer subsidy, further modifications are necessary. An increase in the export tax rate results in a decrease in the price received by producers, which in turn depresses the level of fertilizer application and reduces output. The increase in tax, of course, reduces the net cost of the subsidy to the government at the expense of the sugar producers.

Parameters and Data

This model allows us to calculate private and public sector benefits and costs for achieving self-sufficiency in rice for any one of the four plans specified (mathematical approximation formula in appendix). In order to estimate the

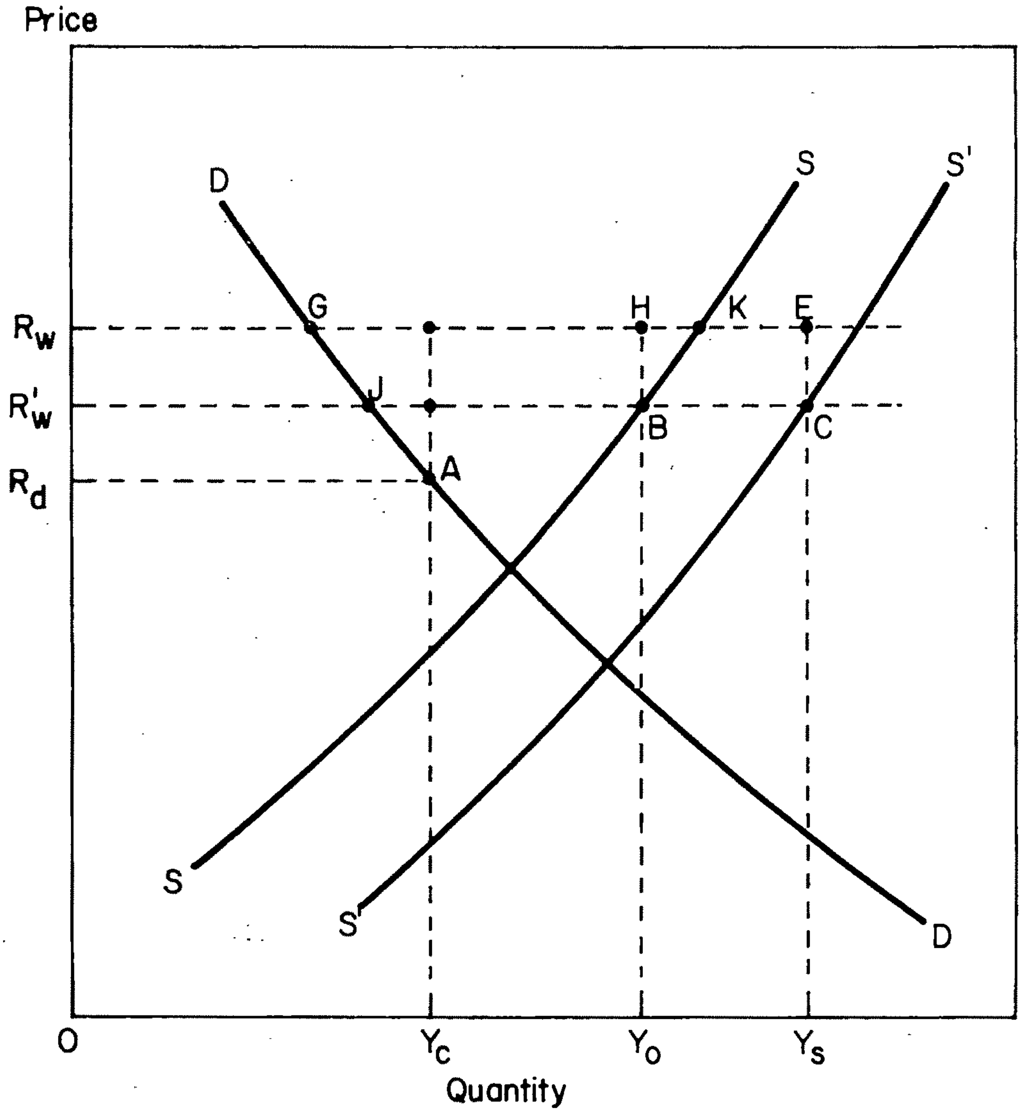

Figure 3. Model of fertilizer subsidy for sugar

benefits and costs, certain parameters and data must be specified. For the purpose of this analysis, we choose 1975 as the base year. Production and consumption relationships with respect to rice, sugar, and fertilizer are estimated for 1975 assuming no price-support or subsidy program. The assumptions made and analysis conducted here are based upon a "normal" relationship between sugar, rice, and fertilizer prices in both the international and domestic markets. Hence, it abstracts from the recent situation of abnormally high prices.

We define a self-sufficiency requirement as the percentage increase in output needed to avoid imports of rice in all but extreme situations such as occurred with the severe drop in domestic rice production due to the floods and droughts in 1972–73. Based upon the record of the past ten years, the added production requirement to achieve self-sufficiency appears to be about 5% of total production or currently around 220,000 metric tons of milled rice.[8]

Assumptions with respect to parameters and data are summarized in table 1. Taxation on sugar export consists of a regular tax (6% *ad valorem*) and a premium tax (20% on the difference between the current export price and the base export price of $182 per ton). For

[8] Throughout the analysis the quantity of rice is expressed in terms of milled rice equivalents and the exchange rate between the Philippine peso and U.S. dollar is assumed as seven to one.

Table 1. Assumptions for Analysis of Rice Price Support versus Input Subsidy, the Philippines Case

Item	Amount
Domestic consumption of milled rice (q_c)	4,400,000 tons
Domestic output of milled rice (q_o)	4,180,000 tons
Consumption in households of rice producers (60% of total)	2,640,000 tons
Domestic output of sugar (y_o)	2,300,000 tons
Export of sugar	1,500,000 tons
Domestic consumption of sugar (y_d)	800,000 tons
Fertilizer input for sugar (45% of total) (z_o)	330,000 tons
Fertilizer input for rice (41% of total) (x_o)	300,000 tons
Increase in output of milled rice to achieve self-sufficiency	220,000 tons
Export price for sugar (r_w)	\$440/ton
Domestic consumer and import price for rice (P_d and P_w)	\$300/ton
Domestic retail price for fertilizer (26N, $7P_2O_5$, $3K_2O$) (P_{fo})	\$160/ton
Ratio of a unit processing and marketing cost to the export price of sugar (m_s)	35%
Ratio of a unit processing and marketing cost to consumer price of rice (m_r)	30%
Ratio of a unit marketing cost to the retail price of fertilizer (m_f)	15%
Price elasticity of demand by fertilizer with respect to rice and sugarcane, absolute value (γ and ϵ)	0.5
Price elasticity of rice supply (β)	0.3
Production elasticity of fertilizer with respect to rice and sugarcane (α and δ)	0.1

plan C, the premium tax rate is increased to 23% and 26% for the subsidy rates that correspond to the 97.5% and 100% levels of rice self-sufficiency.

The estimate of the elasticity of rice supply is based upon the time-series analysis of Mangahas, Recto, and Ruttan. The production and demand elasticities for fertilizer with respect to rice are based on the recent analysis of David using survey data from Laguna Province and are further supported by the results of experiments conducted by Mandac in farmers' fields in Central Luzon.

Our judgement regarding the magnitude of the elasticities for sugar is based upon an examination of nitrogen response experiments conducted by the Philippine Sugar Institute and reported in a study of fertilizer demand by Rodriguez. The average per hectare input of nitrogen for sugarcane is much larger than for rice, and it is clear that the response functions differ in that the maximum yield level of nitrogen input for sugar is more than double that for rice. The magnitude of the elasticity estimates is sensitive to modest changes in the assumed shape of the typical production function. We have purposely been conservative in choosing elasticities of nitrogen for sugar equal to those for rice.[9]

The marginal value product (MVP) per ton of fertilizer in rice and in sugar production was estimated using the data and parameters specified in table 1: MVP for rice = $\alpha(q_o/x_o)\,(1 - m_r)p_d$ = \$293 per ton, and MVP for sugar = $\delta(y_o/z_o)\,(1 - m_s)\,r_w$ = \$200 per ton, which are both substantially higher than the domestic retail price of fertilizer (\$160 per ton).

Recent research on the constraints to increased rice production in the Philippines supports our general assumption that despite the rapid spread of modern varieties there are many regions of the Philippines where fertilizer use is still well below the optimum (International Rice Research Institute, p. 24). In the case of sugar there is a considerable gap in the level of fertilizer use between the more progressive large farmers in Negros and the small producers in Luzon and in some of the newer districts elsewhere in the Philippines.[10]

[9] In sugar, the actual nature of the output response is dictated not only by the farm level response to price but also by the milling capacity, which in the short run is reasonably fixed. In this analysis, the industry is assumed to be operating at a level where mill capacity is not acting as a constraint on output.

[10] Such disequilibria in the levels of modern inputs in agriculture

Evaluation of Policy Alternatives

The estimated benefits and costs of price-support and fertilizer-subsidy programs are summarized in tables 2–4. The choice among policy alternatives can be based on the valuation of a number of criteria. These include (*a*) the cost of the program to the government (or taxpayer), (*b*) the efficiency of the policy in terms of total benefits to the society relative to cost of the program, (*c*) the distribution of benefits and costs among various sectors of society, and (*d*) the savings in foreign exchange. These criteria are measured in terms of the differences from the check case of rice import at AB to maintain the consumer price at OP_d (figure 1).

The policy alternatives are compared in table 2 in terms of the first two criteria. Income distribution effects are shown in table 3, and the effect of alternative programs on foreign exchange in table 4. In aggregating the foreign exchange savings into social benefits in tables 2 and 3, we have tentatively assumed the foreign exchange premium to be 5% based on the difference between official and black market rates of exchange.

The calculations are made for two levels of rice self-sufficiency rate defined as the ratio of domestic output to domestic consumption (i.e., 97.5% and 100%). In order to attain those levels of self-sufficiency, domestic output of rice must be increased from 4,180 metric tons to 4,290 and 4,400 metric tons, implying that the rates of increase in output are 2.63% and 5.26%, respectively. Given output and price elasticity assumptions, these rates of increase can be achieved either by raising the rice price by 9% and 18.6%, respectively, or by lowering the fertilizer price by 40.6% and 64.1%, respectively.

The findings from the analysis can be summarized as follows.

(*a*) The total social benefit produced by the rice price-support program is quite large ($73 million), but since the direct cost of government for the support is even larger ($106 million), the net social benefit is negative (table 2).

(*b*) The substantial net social benefit produced from the subsidy on fertilizer may at first seem to be an anomaly because price distortions due to the government intervention in product or input markets usually result in inefficiency or net loss in social and economic welfare. It has to be remembered, however, that we are dealing with an economy characterized by suboptimality in farmers' application of inputs and that our benchmark is not free market equilibrium.

(*c*) Among the fertilizer price subsidy alternatives, the net social benefit for plan A ($16 million) is lower than for plans B and C ($20 million), but the direct government

have been found even in developed economies such as the United States (Griliches) and Japan (Hayami et al., pp. 96–99).

Table 2. Benefits and Costs Associated with Price-Support and Fertilizer-Subsidy Programs

	Self-Sufficiency Rate	
	97.5%	100%
	----Million $-----	
Total social benefit[a]		
Rice price support	34	73
Fertilizer subsidy		
A	35	67
B	67	128
C	66	127
Net social benefit[b]		
Rice price support	−14	− 33
Fertilizer subsidy		
A	10	16
B	14	20
C	14	20
Direct government cost		
Rice price support	48	106
Fertilizer subsidy		
A	25	51
B	53	108
C	53	107
Net government cost[c]		
Rice price support	48	106
Fertilizer subsidy		
A	25	51
B	48	98
C	36	72
	Benefit-Cost Ratios	
Total social benefit/ direct government cost		
Rice price support	0.71	0.69
Fertilizer subsidy		
A	1.39	1.31
B	1.26	1.18
C	1.26	1.20
Total social benefit/ net government cost		
Rice price support	0.71	0.69
Fertilizer subsidy		
A	1.39	1.31
B	1.38	1.30
C	1.85	1.77

[a] Total social benefit = producers' benefits + increases in government revenue + foreign exchange premium (assumed as 5% of total foreign exchange savings).
[b] Net social benefit = total social benefit − direct government cost.
[c] Net government cost = direct government cost − added tax revenue from increased sugar export.

Table 3. Income Redistribution Effects of Price-Support and Fertilizer-Subsidy Programs

	Rice Self-Sufficiency Rate	
	97.5%	100%
	--------Million $-----	
Rice price support		
Rice producers	33	70
Sugar producers	0	0
Government[a]	−47	−102
Fertilizer subsidy—plan A		
Rice producers	34	65
Sugar producers	0	0
Government[a]	−24	−49
Fertilizer subsidy—plan B		
Rice producers	34	65
Sugar producers	26	50
Government[a]	−46	−95
Fertilizer subsidy—plan C		
Rice producers	34	65
Sugar producers	14	24
Government[a]	−35	−69

[a] Direct government cost of price support or subsidy program net of government tax revenue and foreign exchange premium (assumed as 5% of total foreign exchange savings-earnings).

cost for plan A ($51 million) is only about half that for the other alternatives (table 2). However, plan A, based on a two-price system in which only rice (and corn) producers are entitled to purchase subsidized fertilizer, has proved difficult to implement administratively especially when there is a fairly substantial gap between subsidized and nonsubsidized prices encouraging black market activities.

(*d*) Despite the high direct government cost for the single-price system of fertilizer price subsidy, the net government cost can be reduced by increasing the export tax on sugar ($72 million for plan C versus $98 million for plan B). Based on net government costs, the benefit-cost ratio for plan C (1.77) is higher than for any of the other alternatives (table 2).

(*e*) Rice producers gain considerably in terms of income benefits in each of the four alternatives being compared. Plans A, B, and C differ principally in the way costs and benefits are partitioned between the government and sugar sector (table 3). Under plan B, both rice and sugar producers gain in similar magnitude at a large cost to the government. Under plan C, the gain of rice producers is almost three times that of sugar producers. However, considering the fact that the area planted to rice is six times larger than the sugar area (3 million versus 500,000 hectares) and the proportion of the population engaged in rice production is even larger, plan C seems more equitable than plan B as a means of income transfer.

Table 4. Total Earnings-Savings in Foreign Exchange Due to Rice Price-Support and Fertilizer-Subsidy Programs

	Rate of Rice Self-Sufficiency	
	97.5%	100%
	------Million $-------	
Rice price support	31	62
Fertilizer subsidy		
A	21	39
B	34	62
C	33	61

(*f*) Rice price support gives a substantially larger contribution to foreign exchange savings than plan A of fertilizer subsidy, since the import expenditure for rice is eliminated with less additional expenditure for fertilizer import. However, there is no difference in savings between price support and plans B and C (table 4).

Conclusions

We have developed a model to compare in a fairly limited context the benefits and costs associated with alternative rice price-support and fertilizer-subsidy programs to achieve self-sufficiency. It should not be implied from this analysis that achieving self-sufficiency through any of these alternatives discussed is a desirable policy goal for the Philippines. There are not only alternative ways of achieving self-sufficiency but also alternative goals to self-sufficiency that may be more desirable.

What we do argue, however, is that in a period of highly volatile food grain and fertilizer prices, such as we have recently experienced, food staple self-sufficiency and the related price-policy objectives to achieve this goal have become a matter of major concern to many developing countries. The major constraint facing these governments is the budget.

Our results show that a subsidy on the price of fertilizer applied to the rice sector only requires less cost to the government for the achievement of self-sufficiency (plan A). It is more efficient than rice price support in terms of the benefit-cost ratio. However, past experience has shown that it is difficult to limit the fertilizer subsidy to the rice sector because the increase in the gap between the subsidized

and the unsubsidized prices promotes a large-scale diversion of fertilizer from the rice to the sugar sector through the black market. As the diversion becomes larger, the cost to the government will increase and approach the cost under a single-price system (plan B).

The increase in government cost due to an expansion of the fertilizer-subsidy program to cover both rice and sugar sectors can be compensated for by the increase in export tax revenue if the rate of sugar export tax is increased corresponding to an increase in the subsidy rate (plan C). Efficiency in the use of government funds in terms of total social benefit to net government cost is highest for this scheme. It also seems more equitable in terms of the subsidy per person engaged in rice and sugar production.

The fact that the government has been trying to maintain the two-price system for fertilizer seems to suggest a short-run focus of government policies. For the policy maker the direct government cost of the program, which can be budgeted initially, would probably be a more important consideration than the possible income that may be derived in the program in the future through the export tax on sugar or other tax gains that may result from higher farm incomes.

It has to be emphasized that our analysis in this paper is based on "normal" price relations in the Philippines. The benefits and costs of alternative programs change as price relations change. It seems more reasonable to hypothesize that policy makers make a policy choice in relation to specific price relations in specific periods rather than "normal" relations. In order to make more meaningful inference on the decision of policy makers, it would be necessary to extend our calculations for the different sets of price relationships that are specific to the history of the country.

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Appendix

Formula to Estimate Benefits and Costs Associated with Alternative Policies

In order to estimate the benefits and costs of alternative policies shown in figures 1 through 3, a simple power function with a constant elasticity is assumed for production, demand, and supply functions. The following notation is used: price elasticity of rice supply = β, production elasticity of fertilizer with respect to rice = α and with respect to sugar = δ, and price elasticity of fertilizer demand with respect to rice = $-\gamma$ and with respect to sugar = $-\epsilon$.

Price support. The cost to the government or difference between procurement cost and sales revenue is

$$\text{(A.1)} \qquad \text{area } ACLM = (p_s - p_d)(q_c - h).$$

Reduced revenue from government imports is

$$\text{(A.2)} \qquad \text{area } ABEI = (p_d - p_w)(q_c - q_o),$$

where $p_d = OP_d$, $p_s = OP_s$, $p_w = OP'_w$, $q_o = OQ_o$, $q_c = OQ_c$, and $h = OH$ in figure 1.

The relation between p_d and p_s can be established as $p_s = p_d(1 + k)^{\frac{1}{\beta}}$, where $k = (q_c - q_o)/q_o$.

Since we assume a constant-elasticity supply function—$q = \Phi p^\beta$—where Φ is a scaler including supply shifters, an increase in rice producers' income due to government support is calculated as

$$\text{(A.3)}\quad \text{area } BCLM = \text{area } BCP_sP_d - \text{area } MLP_sP_d$$
$$= (1 - m_r)\left[\int_{p_d}^{p_s} \Phi p^{\beta} dp - h(p_s - p_d)\right]$$
$$= (1 - m_r)\left[\frac{1}{1+\beta}(p_sq_c - p_dq_o) - h(p_s - p_d)\right],$$

where p_d and p_s are measured at a retail level, and m_r is the rate of processing and marketing margin for rice (the margin assumed proportional to the retail price).

The net savings of foreign exchange is

$$\text{(A.4)}\quad \text{area } ABQ_oQ_c - \text{increase in fertilizer import} = p_w(q_c - q_o) - p_{fo}(1 - m_f)(x_c - x_o),$$

where p_{fo} is the domestic retail price of fertilizer, x_o and x_c are the fertilizer inputs corresponding to p_d and p_s, respectively, and m_f is the rate of marketing margin for fertilizer. The relation between x_o and x_c is established as $x_c = x_o(p_s/p_d)^{\gamma}$.

Fertilizer subsidy for rice. The fertilizer input required to produce a self-sufficiency level of rice output (q_c) while other factors remain constant is $x_s = x_o(q_c/q_o)^{\frac{1}{\alpha}} = x_o(1 + k)^{\frac{1}{\alpha}}$. The subsidized price of fertilizer that would induce farmers to apply more fertilizer at the level x_s is $p_{fs} = p_{fo}(x_s/x_o)^{-\frac{1}{\gamma}} = p_{fo}(1 + k)^{-\frac{1}{\gamma\alpha}}$, where p_{fo} and p_{fs} are unsubsidized and subsidized prices of fertilizer for farm producers, respectively. The government cost of fertilizer subsidy for rice to achieve self-sufficiency is

$$\text{(A.5)}\quad \text{area } ABP_{fs}P_{fo} = x_s(p_{fo} - p_{fs}).$$

A reduction (or increase) in government revenue due to a decrease in rice import as a result of achieving self-sufficiency is the same as for rice price support (see equation A.2).

The rice producers' benefit is

$$\text{(A.6)}\quad \text{area } CDP_{fs}P_{fo} + \text{area } ABQ_oQ_c - \text{area } BDX_oX_s = (p_{fo} - p_{fs})x_o + (1 - m_r)p_d(q_c - q_o) - p_{fs}(x_s - x_o).$$

The net savings in foreign exchange is

$$\text{(A.7)}\quad \text{area } ABQ_oQ_c - \text{area } ACX_oX_s = p_w(q_c - q_o) - p_{fo}(1 - m_f)(x_s - x_o).$$

Fertilizer subsidy for sugar. Fertilizer input for sugar corresponding to the subsidized price of fertilizer required for rice self-sufficiency is $z_s = z_o(p_{fo}/p_{fs})^{\epsilon} = z_o(1 + k)^{\frac{\epsilon}{\alpha\gamma}}$, where z_s and z_o are fertilizer inputs at subsidized and unsubsidized prices, p_{fs} and p_{fo}, respectively, while the rice price remains at p_d. The sugar output at the subsidized price of fertilizer is $y_s = y_o(z_s/z_o)^{\delta} = y_o(1 + k)^{\frac{\epsilon\delta}{\alpha\gamma}}$, where y_s and y_o are sugar outputs corresponding to fertilizer inputs z_s and z_o, respectively.

The government cost of fertilizer subsidy for sugar is

$$\text{(A.8)}\quad \text{area } EFP_{fs}P_{fo} = z_s(p_{fo} - p_{fs}),$$

The government revenue from the sugar export tax would increase by

$$\text{(A.9)}\quad \text{area } BCEH = tr_w(y_s - y_o),$$

where r_w ($= OR_w$) is the export price of sugar, and t ($= R_wR_w/OR_w$) is the rate of sugar export tax.

The sugar producers' benefit is

$$\text{(A.10)}\quad \text{area } HGP_{fs}P_{fo} + \text{area } BCY_sY_o - \text{area } FGZ_oZ_s = (p_{fo} - p_{fs})z_o + (1 - t)(1 - m_s)r_w(y_s - y_o) - p_{fs}(z_s - z_o),$$

where m_s is the rate of processing and marketing margin for sugar. The net gain in foreign exchange is

$$\text{(A.11)}\quad \text{area } EHY_oY_s - \text{area } EHZ_oZ_s = r_w(y_s - y_o) - (1 - m_f)p_{fo}(z_s - z_o).$$

By increasing the tax rate from t to t' in plan C, the fertilizer input and sugar output would change from z and y to $z'_s = z_s[(1 - t')/(1 - t)]^{\epsilon}$ and $y'_s = y_s[(1 - t')/(1 - t)]^{\epsilon\delta}$. Costs and benefits associated with fertilizer subsidy for the sugar sector under plan C can be calculated by substituting t', z', and y' for t, z, and y in equations (A.8) through (A.11) except for an additional export tax applied to export $(t' - t)r_w(y_o - y_d)$, where y_d is domestic consumption, which has to be added to equation (A.9) and subtracted from equation (A.10).

Peasant Risk Aversion and Allocative Behavior: A Quadratic Programming Experiment

Thomas B. Wiens

A quadratic risk programming model is used to examine the impact of yield uncertainty on peasant allocation of land among crops and use of hired factor services. The assumption of an exponential utility of income function permits sample estimation of the extent of risk aversion and interpretation of the dual solutions as shadow prices. Historical survey data on a Chinese village are used to show that optimization qualified by risk aversion proves superior to risk neutrality or credit constraints in explaining peasant allocative behavior.

Key words: China, farm planning, quadratic programming, risk aversion.

Quadratic risk programming is commonly considered a theoretically appealing technique for analyzing the impact of risk aversion on farm planning in terms of the trade-off between the first and second moments of stochastic outcomes of farm plans (Hazell, Rae, Freund). It is often recognized that use of the expected income-variance (E-V) criterion of optimality is equivalent to maximization of the expected value of an exponential utility-of-income function if income is normally distributed (Freund). However, it is rarely recognized that in this case the dual solution of the quadratic program has an interpretation analogous to the linear case, and a criterion emerges for measuring the extent of farmer risk aversion from readily accessible data.

In reaction to the limited success of programs in certain less developed countries intended to induce acceptance of technical changes among smallholders, a number of recent microstudies (Baker and Bhargava, Wolgin, Schluter, Roumasset) have examined the relative importance of subjective factors such as risk aversion or liquidity requirements and objective factors such as credit or input availability on peasant decision making, arriving at contradictory conclusions. This study utilizes historical Chinese sample survey data to demonstrate that the behavior of peasants facing market and technological choices comparable to those confronted elsewhere in Asia today exhibited substantial risk aversion, which tended to decrease with farm size. Neither risk neutrality nor liquidity constraints alone could explain both the cropping patterns and the factor employment observed among these farmers.

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The Method of Analysis

Use of the E-V criterion in risk analysis is frequently justified on the assumption that the decision maker's utility-of-income function is quadratic and concave (Hazell, Markowitz). This assumption is theoretically objectionable (Pratt) and eliminates the dual solutions to quadratic risk programming problems as a source of valuable information on both the optimality of resource allocation patterns and the extent of risk aversion of the decision maker. Moreover, the assumption is unnecessary if incomes are approximately normally distributed.

In the latter case, it is far more convenient to assume an exponential utility-of-income function:

$$(1)\quad U(R) = K - \theta \exp(-\lambda R), \qquad \text{for } K,\ \theta, \text{ and } \lambda > 0.$$

Let net income be defined by $R = b'X$ and vector $b \approx N(\mu,\Sigma)$, then

$$(2) \quad E(U(R)) = K - \theta \exp[-\lambda\mu'X + (\lambda^2/2)X'\Sigma X].$$

To maximize equation (2) with respect to vector X of activity levels is equivalent to maximizing

$$(3) \quad W = \mu'X - (\lambda/2)X'\Sigma X = E(R) - (\lambda/2)\,\sigma(R)^2,$$

that is, the exponential utility function yields a conventional E-V objective function in the case of normality (Freund). Moreover, it is apparent that equation (3), which is nonstochastic, represents the certainty-equivalent level of income defined as R^* such that $U(R^*) = E(U(R))$. This is seen by substituting R^* for R in equation (1), setting equation (1) equal to equation (2), and solving for R^*. Since the difference between the expected return and the certainty-equivalent return (CER) defines a risk premium, the latter has monetary value $(\lambda/2)X'\Sigma X$.

In conjunction with a set of linear constraints ($AX \leq C^*$), maximization of the E-V objective function, equation (3), defines a quadratic programming problem with optimal primal solution X^*. The corresponding dual problem evaluates $\emptyset = \partial W/\partial C^* = \partial R^*/\partial C^*$ at $X = X^*$ (Intriligator). Just as R^* can be interpreted as the maximum amount of (certain) income the decision maker would be willing to trade for the stochastic opportunity set described by $R = b'X$, so can $\emptyset = \partial R^*/\partial C^*$ be interpreted as the amount of (certain) income that would be willingly sacrificed for an increment in C^* at $X = X^*$; that is, the dual solutions $\emptyset$ represent true "shadow prices."

Suppose the decision makers are producers maximizing the expected utilities of net revenues according to the above utility function, subject to fixed market prices of the factors of production. Then observed allocative behavior should be optimal, and we may simulate the outcome of their decision problem by treating observed levels of resource use (C^*) as constraints in a quadratic program for which $R = b'X$ defines the gross revenues derived from activities X. If the primal solutions approximate observed choices of production activities and the dual solutions the market prices of factor services, we may be satisfied that the model has correctly described producer behavior. Should some factor markets be inactive or imperfect, the shadow-market price comparison will reveal it without vitiating the analysis (since the objective function ignores factor costs).

The major parameters (μ, Σ, and C^*) of such a simulation can be observed or estimated, but the parameter λ reflecting the risk aversion of the decision maker(s) is manifestly subjective. In previous articles (Anderson, Hazell, Rae) this has been stressed as a drawback of the E-V approach, and it has been presumed that either direct measurement of utility functions or the solution for the full range of E-V frontiers is required to avoid it. In our approach, it is possible to directly estimate the value(s) of λ that come closest to ensuring that primal solutions X are identical with actual activity levels X^* and dual solutions $\emptyset$ approach actual market prices r.

The Kuhn-Tucker conditions for an optimal solution to the quadratic programming problem defined above require

$$(4) \quad \mu_i - \lambda\Sigma_i X - A_i'\emptyset = 0$$

for all nonzero activities i in the solution, where μ_i is the ith element of μ, Σ_i is the ith row of Σ, and A_i is the ith column of A. Substituting X^* for X and r for $\emptyset$, we may estimate λ as

$$(5) \quad \lambda^* \approx (\mu_i - A_i'r)/\Sigma_i X^*.$$

While this should hold for each production activity if all assumptions are exactly fulfilled, in practice an average over all production activities will suffice. Note that λ^* will vary with scale of production, returns to scale, and activity mix.

Hence, the assumption of an exponential utility function permits a rigorous test of the applicability of the risk aversion model based on both primal and dual solutions and allows direct estimation of the elusive risk aversion parameter λ.

Data and Estimation Techniques

The model is here applied to data from a survey of resource allocations among alternative cropping patterns on twenty-one farms in North China over the years 1937–39.[1] The

[1] Sample data from the South Manchurian Railway (Minami Manshu etc., 1939, 1940a, and 1940b). A fuller description of the regional agrarian economy is found in Dittrich and Myers.

sample includes tenant, part-tenant, and fully-owned farms ranging in scale from small (under 0.6 hectares) to atypically large (3.2+ hectares) and representing a relatively commercialized district with good market access. The primary decision problem faced is to determine the amounts of owned and hired factor services to devote to each of three crops—cotton (high and stable yielding but with high cash outlay and intertemporally declining profitability), maize (higher but unstable in yield and profitability with low outlay), and kaoliang, a sorghum variety (low yielding but hardy with low outlay). These crops share a single growing season and are generally substitutable, although cotton requires well-drained land. The local market has ready access to imported supplies and a trivial middleman's margin, so "subsistence requirements" do not dictate a particular cropping pattern.

To capture substitutability of inputs, the unit of choice is assumed to be the "frontier technique," defined as any technically efficient method of producing a value-unit of each crop under optimal growing and harvest conditions. As increasing returns to scale are observable in the sample, separate technique sets are distinguished for seven large (over 2.75 hectares) and fourteen smaller farms, with large farms presumed to have access to small farm techniques. For all farms, years, and crops, thirty-four nondominated combinations of unit input requirements are distinguished as "frontier techniques."[2] The most important of these are shown in table 1.

The activity level X_i for each frontier technique is a nonstochastic choice variable related to realized gross revenues through the function $R = \sum_i b_i X_i$. The vector b is assumed decomposible into its expected value plus stochastic cross-sectional (u_i), intertemporal (v_t), and mixed deviations (w_{it}) due to variations in farm efficiency and natural conditions:

$$b_{it} = \mu + u_i + v_t + w_{it}, \tag{6}$$

where i is farm unit and t is crop year. Treating b_{it} as pertaining to a particular crop rather than a single technique, the expected values are estimated by regressing realized yields on frontier yields (suppressing the intercept), where frontier yields for each farm and crop year represented the maximum potential yield for each crop (as estimated using conventional linear programming techniques) given the frontier techniques and the input levels actually employed.

[2] "Frontier" estimation techniques, while required to distinguish efficient production processes, are sensitive to errors of observation (Timmer). A very few observations are rejected as containing probable errors. A fuller discussion of the methodology and data may be found in Wiens.

Table 1. Resource Requirements per Chinese Dollar of Expected Value of Product (1937 Prices)

	Land (ha./100)	Labor (days)	Animal Labor (days)	Fertilizer ($)	Other Capital ($)
Large farms					
Corn	0.473	0.299	0.030	0.055	0.055
	0.440	0.652	0.069	0	0.016
	0.347	0.444	0.045	0.116	0.029
Kaoliang	0.680	0.581	0.055	0.003	0.059
Cotton	0.300	0.596	0.005	0.140	0.038
	0.367	0.587	0.032	0.152	0.020
Small farms					
Corn	0.813	0.621	0.043	0.004	0.020
	1.000	0.900	0.005	0.096	0.040
	0.693	0.401	0.064	0	0.031
	0.300	1.437	0.045	0.036	0.019
	0.627	0.365	0.005	0.005	0.105
	0.453	0.615	0.051	0.050	0.078
Kaoliang	1.367	0.893	0.064	0	0.019
	0.733	0.758	0.015	0	0.041
	0.913	0.300	0.055	0	0.103
Cotton	0.313	0.683	0.019	0.153	0.020
	0.340	0.792	0.016	0.143	0.020
	0.253	0.699	0.017	0.097	0.022

Note: The above represent a sample of alternative "frontier" techniques for producing each crop. Only those appearing in optimal quadratic programming solutions for one or more farms are shown.

The residuals of these regressions could be used as a measure of the stochastic elements in the farmer's choice problem, if purged of the irrelevant cross-sectional components. A two-way balanced cross-classification analysis of variance technique (Graybill) is used to estimate Σ, with strictly cross-sectional components removed.

Constant prices are assumed in the estimation of μ and Σ, but the estimates are subsequently adjusted for intertemporal changes in price expectations based on a one-year lag model. While inadequate data existed to account for the variance of realized prices around expectations, it appears that the magnitudes involved are insignificant relative to intertemporal variance-covariance of yields (see table 2). Comparing similar findings for India (Schluter), this suggests that price risk can frequently be disregarded in studying production decisions in peasant agriculture.

The estimates of μ and Σ used as parameters in the quadratic objective function (at 1937 prices) are given in table 3. The estimated parameters confirm the assessment of risk return characteristics of each crop given above.

Estimates of the risk aversion parameter λ are separately derived for large and small farms (0.0085 and 0.091, respectively) using relation (5). While results could benefit from estimation of a separate value for each farm, for this exercise it is felt sufficient to show that the average behavior of a group of farms of similar size (or wealth) could be accounted for in terms of a single average extent of risk aversion. Not surprisingly, it is found that decreasing absolute risk aversion with increased wealth is required to explain the behavior of both groups, implying a tendency for the distribution of income to worsen over time (see Weeks).

Table 2. Proportional (Logarithmic) Variance-Covariance of Prices and Yields around Their Expected Values

	Variance			
	Corn	Cotton	Covariance	r_{xy}
Price	0.023	0.017	−0.002	−0.11
Yields	0.261	0.071	0.067	0.50

Note: Price (logs) variance-covariance computed from Nanking fourth quarter wholesale price series, 1920–36 (a long farm gate price series was unavailable), with expected prices assumed equal to lagged actual prices. Prices series for kaoliang were unavailable. Yield (logs) variance-covariance around estimated expected values from sample data, with cross-sectional variance-covariance removed. The simple correlation coefficient for the pair of crops is r_{xy}.

Table 3. Estimated Parameters of the Objective Function (1937 Prices, Chinese Dollars)

	Corn	Kaoliang	Cotton
$E(b)$	0.799	0.748	0.837
Σ_b			
Corn	0.048	0.017	0.025
Kaoliang	—	0.032	0.003
Cotton	—	—	0.025

Note: $E(b)$ estimated by regressing realized yields on frontier yields (suppressing the intercept). Σ estimated from the residuals of the regressions using two-way balanced cross-classification analysis of variance (Graybill).

Findings

Solutions of the quadratic programming problem, along with those of the comparable linear programming problem, are obtained for each farm and year in order to test the hypothesis of risk averse behavior against the alternative of risk neutrality.[3] To explore the relationship between credit availability and resource allocation, solutions to both problems are also obtained on the assumption that working capital (or "liquidity") is the only ultimate constraint.

The results of risk neutral linear programming solutions are distinctly contrafactual (average risk neutral solutions for a subgroup are given below). Given the levels of resources employed, the sample farms should with few exceptions be diversified between cotton and maize with no sorghum grown and with emphasis on cotton in 1937 shifting drastically to emphasis on corn by 1939. Dual solutions are on average significantly higher than market prices for all factors except fertilizer (which had too low a shadow price), indicating overall insufficient hiring of factor services. Because of increasing returns, shadow prices tend to be higher on large farms than on small.

When working capital is treated as the sole constraint, specialization in cotton or maize at various times appears optimal (with labor intensity lower than observed) and the rate of return to working capital exceeds 75% per crop season, sufficient to justify recourse to moneylenders (at a 24% annual interest cost). Nor does it appear that, in the context of this

[3] Computer processing is based on an efficient algorithm similar to one suggested by Shetty.

marketing and cropping system, a more complex model of liquidity requirements would improve the verisimilitude of solutions (see Baker and Bhargava).

By contrast, the risk aversion model accords quite well with the average behavior of the sampled peasants. Primal solutions in general call for full diversification among the three crops in proportions close to those observed (see table 4). Moreover, since in the course of general price inflation (which raises risks disproportionately to expected returns) risk and price effects work in opposite directions, the optimal crop proportions show greater stability over time than is found in risk neutral solutions, explaining an apparent anomaly in sample farm behavior.

Risk aversion also generally reduces the difference between dual solutions and market prices (see tables 5 and 6). Indeed, for those factor services with active markets, divisibility, and correct specification (in particular, labor and land), the average levels of use are close to optimal. For these factors, too, the variance of dual solutions for different farms is relatively low, indicating that individual deviations from optimality are rarely serious.

Dual solutions diverge in varying degrees from market prices of other factor services (cotton land, animal labor, fertilizer, and other capital), and display dispersed and bimodal distributions (either zero or high in value). Many farms appear to make wasteful use of their animal labor and fertilizer, while others seem starved for these services. These results probably indicate specification error and market imperfection rather than suboptimal or risk neutral peasant behavior.

The separate restriction on cotton land is added to account for the requirement of well-drained land for this crop. Most likely, such land is higher yielding in other uses as well (not accounted for in our technical coefficients), hence the persistence of high market rentals for such land even when not planted in cotton.

Although the average shadow prices for fertilizer are not far from market prices, the model does not account for the bifurcation of that input into two distinct types—slow-acting organic base fertilizers and fast-acting top dressings (bean cakes and animal byproducts), nor is it clear how the survey attributes prices to these different items (the first largely self-supplied at near-zero labor cost during the slack season). Such heterogeneity could account for high variance of dual solutions.

The high and varying shadow prices of animal labor and other capital (the latter primarily depreciation of tools and implements) originate largely in indivisibility and the absence of an active rental market. Because of tight cultivation schedules imposed by a short growing season, peasants cannot afford to depend upon their neighbors for use of animals or implements, although a few personalized transactions occur at prices tied to wage rates (for plowing, about 1.6% of potential animal labor days). Farms that opt to buy and maintain animals and implements could frequently have excess capacity and other farms apparent shortage as indicated by high shadow prices, yet the addition or removal of a discrete unit (e.g., one labor animal) need not be economically justified. Integer programming techniques must be used to account for such indivisibilities in farm planning models (Gotsch and Yusuf).

Table 4. Crop Production as a Percentage of Land, Actual and Optimal under Risk Aversion

Sample	Corn		Kaoliang		Cotton	
Farms	Actual	Optimal	Actual	Optimal	Actual	Optimal
Large						
1937	8.1	16.4	31.4	25.2	60.5	56.0
1938	11.9	22.5	31.2	23.8	56.9	53.7
1939	10.4	10.0	34.7	37.9	54.9	50.7
Small						
1937	12.0	19.1	24.8	22.9	63.2	56.1
1938	19.0	18.1	29.4	26.2	51.6	52.4
1939	15.4	17.6	33.4	32.0	51.2	45.1

Note: All figures above are based on means of actual or optimal solution values for the size-year class of farm. Optimal percentages do not necessarily add to 100, since solutions called for a small percentage of land left fallow. Both actual and optimal proportions reflect changes in relative prices expected, as implied by the following (based on farm gate prices). The indices of cotton-corn price relatives for 1936–39 are 121, 100, 90, and 51, respectively. The indices of kaoliang-corn price relatives for 1936–39 are 109, 100, 101, and 108, respectively.

Table 5. Mean Certainty-Equivalent Shadow Prices for Large and Small Farms and Market Prices of Factor Services

	1937	1938	1939
Land			
Large	16.79	14.24	13.58
Small	19.09	12.61	20.24
Market	24.61	21.64	24.18
Labor			
Large	0.49	0.58	0.70
Small	0.34	0.63	0.65
Market	0.45	0.55	0.70
Fertilizer			
Large	0	0.20	0.67
Small	0.51	0.34	0.52
Market	0.32	0.44	0.56
Cotton land			
Large	37.27	22.55	16.55
Small	39.76	13.39	23.45
Market	28.61	34.61	36.91
Animal labor			
Large	0.31	0.70	6.39
Small	10.10	5.41	5.67
Market	0.80	1.00	1.20
Other capital			
Large	3.61	4.70	5.36
Small	4.31	5.24	6.39
Market	1.00?	?	?

Note: Sources of Market Prices: land (ordinary) and cotton land (well-drained)—previous year's mean reported rental value (+10% where rent prepaid); land rentals contracted for one year in advance. Labor—modal daily labor payment (including value of commodities supplied). Animal labor—modal rate per day for animal plus plow or baskets if hired (based on a limited number of transactions). Fertilizer—based on values of fertilizer utilized as attributed by survey researchers; organic fertilizer nutrient content is absorbed over four years in roughly equal amounts (manure); the capital recovery rate on one dollar is $0.32, given an interest rate of 10%, hence is the level of return justifying the purchase of an additional $1 unit; values during 1938–39 were computed by adjusting this figure according to an estimated price index of fertilizer. Other capital—includes seeds, tools and implements, and storage facilities, evaluated at their rate of depreciation based on age and original cost; however, the latter may be well below replacement cost (unknown), hence the assigned 1937 unit cost of $1 may be too low.

An alternative explanation for the high shadow prices of some types of capital service could be the presence of a shortage of long-term credit (Wolgin, Baker and Bhargava). Such credit is available through a land mortgage market but at high effective rates of interest (20% to 30%). Some conclusions on the extent of shortage can be drawn by replacing the factor service constraints with a single working capital constraint (preserving the fiction that a rental market in capital services exists, making long-term capital unnecessary). It is found that peasants could reduce their working capital burden by substituting the services of land, animal labor, and tools and implements for hired labor and purchased fertilizer, while maintaining full diversification. In this case, the CER to working capital would be low or slightly negative, so that even short-term borrowing at subsidized rates of interest would not be attractive. Such low returns of course do not imply that peasants should employ more of their liquid assets in moneylending, for this alternative involves risks no less severe and need not appear attractive to risk averters.

Since the rental market in capital services is in fact underdeveloped, it can be presumed that actual CER's are lower still. Hence, while the fundamental constraints on farm resource allocation and expansion includes the farms' own stocks of liquid assets and the indivisible nature of certain capital inputs, it does not follow that improved credit availability, even at moderate rates of interest, would induce borrowing for productive purposes. Only substantial reductions in the peasants' subjective risk premia would induce such borrowing.

The sensitivity analysis for small farms (table 6) suggests that the effects of policies to reduce risk or risk aversion are technology-specific and sometimes ambiguous. For example, in this sample, a risk-reducing crop (cotton) also is fertilizer-intensive, hence risk aversion tends to increase peasant demand for fertilizer (and crop insurance might have decreased it). Nor is the acreage in cotton a monotonically increasing function of the extent of risk aversion as might be supposed, for at some point land-intensive cotton-producing techniques are optimally replaced by fertilizer-using techniques to free land for low risk sorghum production.

Conclusions

The historical age of the sample data used in this study might seem to limit the applicability of conclusions to current policy. Yet neither the attitudes nor the objective circumstances of the Chinese peasant circa 1930–40 can be shown to differ in substance from those of many peasants in Asia and elsewhere today. The one major difference in circumstance (ignoring institutional and other changes in the socialist countries) contributes to the relevance of this study. Whereas the Chinese peasants were familiar with the risks inherent

Table 6. Sensitivity Analysis, Risk Aversion Parameter; Small Farms, 1939

	Crop Proportions[a]			Shadow or Market Prices[b]					
	Corn	Kaoliang	Cotton	Land	Cotton Land	Labor	Animal Labor	Ferti-lizer	Other Capital
Optimal, $\lambda = 0$	0.51	0	0.42	34.30	36.42	0.81	7.22	0.35	10.55
Optimal, $\lambda = 0.0085$	0.34	0.16	0.44	26.24	28.18	0.73	6.52	0.41	8.48
Optimal, $\lambda = 0.0170$	0.21	0.29	0.46	20.97	22.24	0.68	5.78	0.43	6.47
Optimal, $\lambda = 0.0191$	0.18	0.32	0.45	20.24	23.45	0.65	5.67	0.52	6.39
Actual	0.15	0.33	0.51	24.18	36.91	0.70	1.20	0.56	?

[a] May not add to 1.0 due to existence of some slack land in programming solutions.
[b] See notes to table 5 for explanation.

in their opportunity set, many peasants today face new technological choices involving incalculable risks and could well act with far more caution.

Nevertheless, since risk is shown to have had such an overwhelming role in determining peasant resource allocations in this sample (compare also Schluter, Wolgin), a firm conclusion is that policies to reduce risk or otherwise overcome risk aversion would be important instruments for inducing productive change in similar rural economies. Aside from their efficacy in inducing greater specialization and more extensive use of hired inputs, the exercise of such policies might well make peasants more responsive to other familiar instruments, including price and credit manipulation policies.

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The Measurement of Economic Uncertainty in Public Water Resource Development

Bernard W. Taylor and Ronald M. North

The existing benefit-cost criteria for evaluating water resource projects are deterministic and therefore incomplete, since the uncertainty inherent in project outcomes is not considered. A Monte-Carlo simulation approach is used to generate a mean and standard deviation for the benefits, costs, benefit-cost ratio, and net present value for the controversial Spewrell Bluff Project. Subjective estimates defining probability distributions of project benefits and costs were obtained from the Corps of Engineers. A project selection process that includes probability considerations in the benefit-cost criteria is recommended and several approaches for including uncertainty as a variable are suggested.

Key words: benefit-cost analysis, simulation, Spewrell Bluff, uncertainty, water resource evaluation.

A serious limitation of benefit-cost analysis as practiced by federal agencies has always been the questionable assumption of economic certainty when estimating project benefits and costs. Attempts to include the element of uncertainty in the economic evaluation of water resource projects have been sporadic (Hufschmidt and Fiering, James and Lee, McKean, Turnovsky).

The computation of statistical parameters (i.e., a mean and standard deviation) that reflect the variability of project outcomes has been a perplexing problem. Since water resource projects are unique and singular in nature, historical data for the purpose of describing probability distributions are not available. The authors suggest an application of the Monte-Carlo simulation technique, which employs subjective probabilities in order to generate mean benefit-cost values and a standard deviation for improving project evaluation by measuring uncertainty. This methodology was tested on a limited basis via a case analysis of the Spewrell Bluff Dam Project in Southwest Georgia.

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Benefit-Cost Analysis and Uncertainty

In a world where imperfect knowledge is pervasive, taking account of uncertainty in the analysis of public investments should extend beyond purely theoretical discussions (Hirshleifer and Shapiro). The concept and treatment of uncertain expectations in water resource projects has remained somewhat nebulous to economists and decision makers (Haveman). The conceptual difficulties have been large and the "state of the art" in the fields of applied economics, finance, and water resources evaluation has yet to provide a solution. As a result of this lack of development, benefit-cost analysis has typically made the questionable assumption of certainty in the evaluation of water resource projects. Some have claimed that certain intuitive, ad hoc adjustments or subjective judgments were made for uncertainty factors (Hirshleifer and Shapiro). In fact, neither the federal agencies nor the major theoretical contributors in the field of water resource development alter the benefit-cost investment criteria because of uncertainty (Margolis).

However, McKean notes the exclusion of economic uncertainty in the evaluation processes employed by government water resource agencies as a significant deletion. He describes the costs and benefits arrived at through agency analyses as only estimates or expected outcomes. As a result two projects,

A and B, may offer identical average outcomes yet differ greatly with respect to other possible outcomes. These differences may be a matter of some importance if A's possible results are nearly the same as its average, but B's outcome possibilities range from "fabulous success to utter disaster" (McKean, p. 64).

The most common method suggested to incorporate uncertainty into the water resource investment decision is to add a risk premium to the discount rate in the present value algorithm. Eckstein (in discussing uncertainty related to time) concludes that a risk premium of ½% to 1% added to the interest rate appears to be the most appropriate adjustment for risk in project evaluation. However, he would still present to Congress only expected values based on this new interest rate with a risk premium. This method of recognizing project uncertainty is in essence the same as the certainty-equivalence approach presented by Hicks and Lange for the evaluation of private investment (Modigliani and Miller).

The inability to reliably determine risk premiums makes this method open to question. In addition, the ½% to 1% rate suggested by Eckstein seems to be a rather mild adjustment for projects with an expected life of between 50 and 100 years, especially since project planners may not be sensitive to small differences in discout rates. He attempts to justify the low risk premium and this method in general by viewing the government as a firm and projects as one of its investments and then observing whatever risk the government as a whole incurs because of a single project (Margolis).

While the argument for a risk premium results in an adjustment for uncertainty in the correct direction (which is the reduction of present value with project life), it "misses the major problem" (Margolis, p. 102). The responsible government agency and Congress must select the best possible projects and this choice should be "affected not only by the expected values of the projects but also by the probabilities of a range of benefits and costs, i.e., a measure of variability" (Margolis, p. 102). Each major water project can have a significant economic, social, and environmental impact on a particular municipality or region. Because of such impacts the project in question should be fully evaluated to include some measure of variability (a range of benefits and costs).

Alternative methods that might be employed to cope with the problems of uncertainty within the benefit-cost framework are suggested by Eckstein as shortening the period of analysis (the economic life of the project) or making safety (or contingency) allowances by arbitrarily raising some categories of costs by a flat percentage or by reducing benefits through price assumptions that are below expected prices. (These same approaches are suggested by the federal government in their guidelines for water resource project evaluation [U.S. Government 1950, 1971, and 1973].)

As noted by Margolis, these methods do not solve the problem of uncertainty any more than the use of a risk premium. Eckstein also notes the difficulty in applying these methods and the kinds of considerations necessary for deriving safety allowances. The question of uncertainty remains so unclear that Eckstein is forced to admit that judgment methods, whether verbal or formal, must be used to identify major contingencies and make some provision for the design of reasonable procedures in the face of uncertainty.

A Simulation Approach for the Determination of Project Variability

As Margolis points out, McKean was the first and primary contributor to recognize that public investment decisions should include the consideration of uncertainty. McKean views uncertainty "as an intangible . . . an especially ubiquitous and significant one" (p. 64). The estimates of costs and benefits that accrue from water resource development are only expected outcomes, which contain a significant amount of uncertainty. He notes that it is desirable to reduce uncertainty, but not enough is known about the frequency distribution of outcomes and the resulting probabilities to develop any type of certainty-equivalent as suggested by Eckstein and the federal government.

McKean suggests that some type of ". . . correct quantitative 'results' should usually be multi-valued to show various 'reasonable' outcomes . . ." to the decision maker (p. 68). Since in benefit-cost analysis a frequency distribution based on historical data is out of the question, other quantitative indicators that would include a range of possible project outcomes as a measure of project variability are required.

The difficulty in developing an alternative approach to the single-valued estimate lies in the measurement of the mean and standard deviation. Hertz offers a solution to this problem in his analysis of uncertainty in private capital investment. He notes that probability distributions can be based on probabilistic judgments made by the decision maker. In this approach the manager makes a subjective estimate of the probability of achieving a particular cash flow. This process is repeated for various expected cash flows until a probability distribution (with a mean and variance) is generated for an investment.

Swirles and Lusztig as well as Anthony and Watson offer a similar approach for developing probability distributions. In this instance three estimates for each project return are gathered: a most likely, an optimistic, and a pessimistic. These three subjective estimates form the limits of a triangular distribution. This method for building subjective probability distributions is similar to that employed in PERT (Project Evaluation and Review Technique) analysis. In PERT, three time estimates for each project activity are obtained from the project manager. For this application, instead of time estimates as used in PERT analysis, benefit and cost estimates for water resource projects are used (figure 1).

MacCrimmon and Ryavec and Van Slyke discuss the appropriateness of the triangular distribution (when using three subjective probability estimates) as opposed to the more traditional Beta distribution employed extensively in PERT analysis. MacCrimmon and Ryavec, performing an error analysis on PERT models, note that the incidence of error is less in the mean and standard deviation of the triangular distribution than in the Beta distribution (since the mean and standard deviation of a triangular distribution are given exactly as opposed to the approximations used in the Beta). These authors note that another advantage of the triangular distribution is that the possible range of its standard deviation is more centralized than the Beta assumed standard deviation.

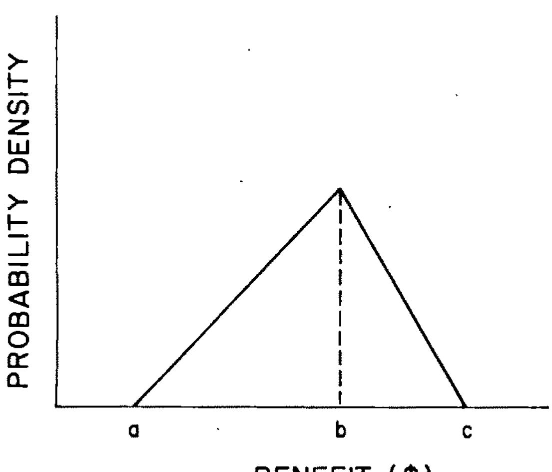

Figure 1. Benefit Density Function, where a = pessimistic, b = most likely, and c = optimistic

MacCrimmon and Ryavec conclude that "since there is no a priori justification (for) . . . a distribution . . . the fact that a mean and standard deviation can be given exactly for a triangular distribution make(s) it equally meaningful, and more manageable. . . . It would be more manageable . . . if it was necessary to use the whole distribution, say in an analysis or a Monte Carlo study" (p. 25). Van Slyke in a comparison of several distributions (e.g., normal, uniform, Beta, and triangular) also found the triangular to be equally acceptable. In addition to this evidence attesting to the validity of the triangular distribution, Swirles and Lusztig as well as Anthony and Watson found the triangular distribution easy to use, and this factor promotes the application and implementation of uncertainty analyses.

The triangular distributions are employed in a Monte-Carlo simulation model to generate the benefit-cost probability distributions. Each triangular benefit and cost distribution yields a process generator for the triangular variates. By successively selecting uniformly distributed random numbers (from a table, etc.), values are generated for each benefit and summed to yield a total benefit value for one simulation run. The same procedure is followed to generate the total cost figure. These two values for total benefits and total costs are then inserted into the appropriate benefit-cost algorithm to yield a benefit-cost ratio (or net present value). However, this is for one simulation only, which yields only one benefit-cost value. By repeating this process for multiple iterations a frequency distribution of benefit-cost values is developed. The frequency distribution resulting from these multiple, simulation iterations is then used to compute a mean and standard deviation.[1]

[1] The reader should not be confused by the Monte-Carlo process. Each simulation produces one value (e.g., a benefit-cost

Any or all of the following benefits may result from a particular water resource project (Howe, James and Lee, U.S. Government 1971): flood control, recreation, water supply, hydroelectric power, irrigation, shoreline development, water quality, navigation, area redevelopment, and others. Costs are of two basic types: project installation costs (capital and project operation) and maintenance and replacement costs (OMR). Government agencies performing benefit-cost analyses assume that the various dollar benefits that result from a project can be uniquely categorized in each of the benefit areas; that is, benefits in any given category (e.g., flood control) are assumed to be uncorrelated with other benefits (e.g., power) once the project has been scaled and designed. In fact, these benefits, once estimated, are fixed by law in the congressional authorization for implementation. Since this simulation experiment was conducted within the traditional (*Green Book* and Senate Document 97) benefit-cost framework and the data are ex ante, we are faced with the agency assumption of independence of benefits at this stage of analysis (U.S. Government 1950, 1962).[2]

The major thrust of this application of simulation to project evaluation is to demonstrate that for any given project there is a significant range of probable outcomes for each project purpose. Such ranges of expected outcomes should be considered in the project planning process to approximate the marginal conditions for efficiency among all purposes. The triangular distribution using Monte-Carlo simulation techniques begins with the assumption of independence of benefits for a project in the advanced stages of design and authorization such as the Spewrell Bluff Dam.

Case Analysis: The Spewrell Bluff Project

The Flint River, one of Georgia's major river systems, originates near Atlanta and flows in a southerly direction to Florida. The middle portion of the Flint River offers a unique, scenic river setting that is also an ideal site for hydropower generation. It is in this region where the U.S. Army Corps of Engineers has proposed and planned a major impoundment project, the Spewrell Bluff Dam.

The Spewrell Bluff project is planned to produce the following tangible benefits: the generation of hydroelectric power, flow regulation for downstream navigation, reservoir recreation, flood control, fishing, and area redevelopment. Power generation and recreation provide approximately 84% of the total benefits (table 1, column 2).

The Estimation Procedure

The subjective probability estimates (i.e., a most likely, an optimistic, and a pessimistic) were obtained by interviews in the authorized planning agency, the U.S. Army Corps of Engineers, Mobile District Office. The estimates were obtained from the various area chiefs for the socioeconomic section, recreation resources section, environmental and resources branch, and the project engineering and configuration section. In each instance the chief of the project development section assisted. Thus, for each project benefit and cost two experienced people made the estimates. A detailed explanation of the purpose of the experiment and the procedure to be followed in making the estimates was given to each participant. This included a thorough explanation of the meaning of the "end points" of the triangular distribution (i.e., points a and c in figure 1).[3]

The estimates were obtained during a several hour interview in which the individual would consult additional information to verify variations or uncertainties in the published figures. Once the procedure was described and all factors that should be taken into account were understood by the interviewee, no attempt was made to alter the individual's estimating procedure nor his estimates. This was done to avoid projecting any bias into the estimates through an unwarranted comment or suggestion. The resulting subjective benefit and cost estimates are believed to be realistic and the best available (table 1).

ratio). A mean and variance is not computed for every benefit distribution (as might be done for time activities in an analytical PERT analysis) and then summed to yield a total benefit-cost value (ratio) and variance. Thus, the possibility of covariances is eliminated.

[2] The existing economic evaluation process accepts certain gross assumptions about the independence of costs from benefits. We know intuitively that this assumption of independence is not necessarily made in the early stage of scaling and design where trade-offs among competing functions are made to optimize the project benefit-cost ratio. We in fact fix these assumptions during the planning process so that judgments may be exercised in the political process.

[3] It is necessary to explain the "end points" in detail so that the subject knows that the probability of a benefit being less than a or greater than b is zero. Moder and Rodgers report on the types of bias that might result from this type of estimating procedure.

Table 1. Subjective Estimates of Spewrell Bluff Project Annual Benefits and Costs

	Subjective Estimates ($)		
Benefit or Cost	Pessimistic	Most Likely[b]	Optimistic
Benefit			
Flood control	847,600	1,173,900	1,485,300
Hydroelectric power	5,034,125	5,922,500	5,922,500
Navigation	25,200	28,000	30,200
Recreation	4,202,000	5,372,000	7,783,000
Fish and wildlife	57,500	127,500	172,500
Area redevelopment	0	830,000	1,192,000
Total annual benefits	10,166,425	13,454,000	16,585,500
Cost			
Total capital cost	192,279,000	179,700,000	162,410,200
Annual cost[a]	7,038,460	6,578,000	5,945,837
Operation and maintenance	2,192,430	2,049,000	1,741,650
Total annual costs	9,230,890	8,627,000	7,687,487

Note: The Corps of Engineers computes all benefit-cost parameters on an annualized basis. That convention was followed in this research.

[a] Total capital cost annualized at a discount rate of 3.25% for a project life of 100 years.

[b] The "most likely" estimates coincide exactly with the initial project benefits and costs as reported in the U.S. Army Corps of Engineers planning document for the Spewrell Bluff Project. Since the project had not been officially authorized for construction, the original benefit and cost estimates remain unofficial.

Once the estimates (which defined triangular distributions) were obtained they were incorporated into a computerized simulation model employing the Monte-Carlo technique. The computer program was developed using the Fortran computer language with two subroutines, "DRAW" and "TABLE." The experiment was conducted for 400 iterations of the simulation model.

The output was divided into five economic parameters describing the benefits and costs of the Spewrell Bluff Project. These included total annual benefits, total annual costs, annualized benefit-cost ratio, total annual net benefits less costs, and total net present value. The statistical mean, standard deviation, and frequency distribution were generated for these parameters (table 2).

The mean (expected value) for each of the five benefit-cost parameters noted in table 2 coincide with the original benefit and cost estimates. This occurrence was expected since in all cases the subjective, most likely estimate coincided exactly with the original deterministic estimate made by the Corps of Engineers. This was a logical procedure on the part of the individual making the estimate, since he would naturally assume that his previous deterministic estimate would be the "most likely."

Table 2. Statistical Results of Spewrell Bluff Simulation Experiment

Economic Parameters	Mean Values ($)	Standard Deviation ($)
Total annual benefits	13,450,270	830,938
Total annual costs	8,516,762	240,281
Total annualized net benefits	4,933,831	858,609
Total net present value	145,717,100	25,362,030
Annualized benefit-cost ratio	1.58	0.11

Application of the Simulation Results

The simulation results are not significant within themselves. A mean outcome and standard deviation standing alone (without some basis for comparison) will not generally provide an answer to the question of the economic acceptability of a water resource project. However, statistical parameters are significant when numerous projects are compared with one another. One project may have a higher mean outcome than another but it also may have a higher standard deviation (indicating a greater amount of risk). The question then becomes one of policy. Which is more preferable—the higher expected outcome or the lower risk? As a result of this dilemma, specific decision rules must be formulated that reflect the taxpayers' preference for risk or risk avoidance.

There are several decision models available to compare alternative private investment projects. However, in order to demonstrate such models for use in the public sector it is necessary to evaluate more than one project. There-

fore, the following three hypothetical water resource projects will be used for demonstration purposes.

Let project 1 produce a mean (M) annual net benefit of \$3,000,000 with a standard deviation (σ) of \$400,000, project 2, which corresponds to the Spewrell Bluff example, produce a mean annual net benefit of \$4,933,831 (848,609), and project 3 produce mean benefits of \$2,500,000 (600,000).

The first decision model discussed is the familiar "coefficient of variation": $V = \sigma/\mu X 100$. This particular measure shows the standard deviation as a percentage of the mean. For the three projects, respectively, the coefficients of variation are $V_1 = 0.14$, $V_2 = 0.17$, and $V_3 = 0.24$.

Project 1 is the most desirable since it has the lowest value for the coefficient of variation (i.e., the least amount of uncertainty relative to the magnitude of the mean value).

The second method is the "safety first" criterion suggested by Roy (Boisvert). In this approach the decision maker (i.e., the public) specifies a minimum acceptable project outcome. Using this minimum level incorporated in Chebyshev's inequality we can determine the upper boundary for the probability of experiencing an undesired outcome:

$$P(\theta \leq \theta^*) \leq P\{|\theta - \mu| \geq \mu - \theta^*\} \leq \frac{\sigma^2}{(\mu - \theta^*)^2}.$$

To minimize the above probability we choose the project that yields the minimum value for $v = \sigma^2/(\mu - \theta^*)^2$. For our example, a minimum acceptable project outcome is established as \$2,000,000 in mean annual net benefits. For the three projects, the minimum values are $v_1 = 0.16$, $v_2 = 0.09$, and $v_3 = 1.44$.

Using this decision methodology, project 2 is the most desirable. As in the previous approach, this method is limited by the difficulty of determining the public's minimum acceptable outcome (θ^*).

A third approach is the use of a graphical investment frontier (as suggested by Markowitz 1959). In this method the mean net benefits of a number of projects are plotted on a graph against the standard deviations of net benefits. Under the assumption that decision makers (i.e., society in the public sector) are risk averters, Markowitz (1952) and Pyle and Turnovsky explain how one can limit consideration to only a portion of all expected value and standard deviation combinations. In their analysis only those values that maximize the mean for given values of the standard deviation are employed (figure 2).

Line AB represents the efficiency frontier for all government projects in the sense that it maps out all possible combinations for which the mean is maximized for each level of standard deviation. It is in a sense the production possibility frontier (all other feasible projects lie above and to the left of AB). Given that the decision makers or society are risk averse and wish to maximize expected utility, Pyle and Turnovsky demonstrate under rather general assumptions that the indifference curves, reflecting the willingness to trade off mean benefits and the standard deviation in benefits, are given by I_1, I_2, and I_3. Since the objective is to reach the highest indifference surface, alternatives that lie above the efficiency frontier line AB (such as point 3) can be eliminated from consideration. If one were to know the shape of the indifference curves, a single point could be selected, in this case, the point X. However, estimating the indifference surface would be a difficult, if not impossible, task. While this procedure is unlikely to lead to a single "best decision," it does provide a basis for substantially restricting the number of alternatives to be considered.

The decision models represented in figures 1 and 2 that might be used to apply the results of the simulation model include several significant assumptions. The first assumption is that decision models typically used by the investor in the private sector could be applied to the public sector. Second, it has been assumed

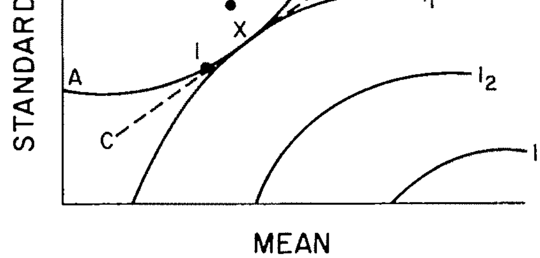

Figure 2. Expected utility maximization

that the public reflects a "risk-averse" attitude that justifies the "safety-first" criteria. It has already been noted in the first section of this paper that "pooling" of risk associated with water resource projects is inappropriate (Margolis). Each water resource project can have a significant impact (socially, economically, and environmentally) on a particular community or region. Thus, the recipients directly affected by the project are concerned with the risk involved.

However, whether the public should be classified as "risk takers" or "risk averters" is subject to some amount of speculation. The authors feel that if projects were evaluated solely on economic considerations the public would tolerate a certain amount of risk taking. But with the increasing emphasis on "multiple objective" planning an opposite trend seems to be developing; that is, the public is now concerned with both the social and environmental (as well as economic) consequences of water resource projects.

The public is becoming increasingly hesitant to accept projects that have an adverse environmental and social impact no matter what the economic gain.[4] Thus, it appears that the public is developing a risk-averse attitude. Given these assumptions and the premise that the public is concerned with risk, it seems appropriate to apply the decision models developed for investors in the private sector to similar situations in the public sector.

One final point should be made concerning the subject of risk in government financed projects. It might be necessary to separate the risks associated with the economic and environmental objectives of a project especially when the values are incommensurate. There may be a tendency in the future, within the multiple objective planning framework, to consider environmental and economic impacts separately. Within this framework an alternative approach to risk evaluation may be taken. Referring to figure 2, once projects are evaluated and found to be inefficient (i.e., project 3) or efficient (i.e., projects 1 and 2) some other values reflecting multiple objectives might be considered in selecting between the efficient projects. These other considerations could include subjective evaluations by the public since environmental and social impacts may be difficult to quantify.

[4] The Flint River/Spewrell Bluff project examined in this paper is an example of the public's concern for the environment. As a result of public pressure former Governor Jimmy Carter vetoed this project 1 October 1973. The Corps of Engineers is now "holding" the project for later consideration.

Summary

This research was undertaken to develop a more realistic alternative to the existing deterministic benefit-cost evaluation procedures. The methodology used to measure project uncertainty was a Monte-Carlo simulation model employing triangular, subjective probability distributions. The proposed Spewrell Bluff Project was used as a case analysis to demonstrate the simulation model and its application to water resources development projects. The simulation results were demonstrated and then compared via investment decision models in a hypothetical example. The authors note that the existing models are limited in application until acceptable methods of determining the public's aversion to risk in water resource projects are developed. Meanwhile, the authors' use of subjective estimates of experienced managers to develop estimates of uncertainty parameters has immediate possibilities of application internally within agencies to improve the project evaluation and selection process.

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Optimum Effort and Rent Distribution in the Gulf of Mexico Shrimp Fishery

Wade L. Griffin, Ronald D. Lacewell, and John P. Nichols

Traditional methods used to estimate fishing effort that maximizes rent to an open access resource have almost universally assumed all costs are directly proportional to effort. When crews receive a fixed share of gross returns, labor costs are proportional to catch; hence, rent accrues to crews as well as vessel owners under limited entry. A model that allowed costs to be proportional to effort and catch was applied to the Gulf of Mexico shrimp fishery. This study indicates that traditional analysis would result in management schemes that overtax vessels and ignore rent accruing to crews.

Key words: common property, fisheries, rent distribution, shrimp.

During the past two decades the basic results of both theoretical and applied articles have shown that the common property nature of fisheries, accompanied with the free entry of labor and capital, results in overfishing (Gordon, Scott, Schaefer, Turvey, Van Meir, Quirk and Smith, Smith, O'Rourke, Bell, Gates and Norton). This crowding externality gives rise to the phenomenon of resource rent dissipation and implies some type of imposed management system if rent is to be maximized to the resource.

In what we term the "traditional" fishery economic literature, the assumption is almost universally made that all costs are directly proportional to effort, where effort is defined as the relative fishing power per day fished aggregated across days fished and vessels.[1] However, when crews are paid a share of gross or net returns instead of a wage, labor costs are proportional to catch rather than effort. Zoeteweij states that the share system is predominant in marine fisheries. Crutchfield and Zellner point out that the reason for the universal use of the share system is that it spreads the inevitable high risk of fishing and provides a direct incentive for teamwork and maximum effort during the season. Whether crew labor costs are proportional to effort or catch, Cheung has shown that in a common property fisheries rent will be dissipated.

Although the assumption that all costs are proportional to effort greatly simplifies an analysis, it can also distort the results. The purpose of this paper is to provide methodology and an empirical application for estimating the economic optimum in a fishery when some costs are proportional to catch. This analysis has implications relative to the economic optimum catch (catch where rent to the resource is maximized) and, even more important, to the distribution of rent from the resource.

To appropriately quantify the distribution of rent to various components of an open access fishery, a needed adjustment to the traditional analysis is inclusion of those costs that are proportional to catch rather than effort. A general conceptual framework of rent distribution in marine fisheries is developed and then applied to the Gulf of Mexico shrimp fishery. Optimum effort, catch, and rent distribution are compared under alternative assumptions regarding the nature of costs. Finally, policy implications are discussed.

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[1] Turvey recognizes the share system but argues that this is not relevant to his case and assumes that total cost rises more than proportionally to effort. O'Rourke also recognizes the share system but assumes the two methods are similar and treats all costs as proportional to effort.

Nature of Fishery Production Costs

Traditional Concepts

Traditional fishery economics assumes all costs items to be a linear function of effort implying that

$$(1) \qquad \Pi = R - C = PY - rE,$$

where Π is rent to all vessel owners in the industry as calculated by the traditional method; R is total revenue to the industry calculated as price of fish—P, assumed to be constant—times total pounds landed by the industry—Y; and C is total cost incurred by the industry and calculated as the unit cost of effort—r, assumed to be constant—times effort exerted by the industry—E.

Applying marginal analysis to the production function between pounds landed and effort or $Y = f(E)$, rent is maximized by employing that amount of effort such that

$$(2) \qquad f'(E) = r/P.$$

Given C and R in figure 1, rent is maximized to all vessel owners in the industry at effort level E^*. As is well established in the literature, equilibrium with open access to the fishery is at E' units of effort, which dissipates all rent.

Proportional Concept

In most marine fisheries, vessel owners incur some costs that are proportional to catch and not effort, such as crew shares (typically the crew receives a share of the catch), packing and handling, social security, and other related items. When part of total cost is proportional to catch and part is proportional to effort, the rent equation becomes

$$(3) \qquad \Pi_v = R - C_e - C_y,$$

where Π_v is rent to all vessel owners in the industry when some cost components are proportional to catch; C_e is total cost proportional to effort incurred by the industry; and C_y is total cost proportional to catch incurred by the industry.

Using this modified conceptual framework, total cost to all vessel owners is $C_p = C_e + C_y$. In this case equilibrium with open access occurs where C_p equals R at effort level E', as shown in figure 1.[2]

[2] In figure 1, C, C_p, and R are drawn to intersect at E' for convenience of illustration only. In fact, C_p may not intersect C at the same point C intersects R.

Total cost proportional to catch (C_y) includes crew shares, packing charges, and other cost items that are proportional to catch. Therefore, C_y can be disaggregated to the following:

$$(4) \qquad C_y = R_c + C^*_y = sPY + r_1Y,$$

where R_c is total revenue going to all crew members in the industry and is calculated as a fixed percentage—s—of total value product —PY; C^*_y is total cost proportional to catch, incurred by all vessel owners in the industry, other than crew shares and is calculated as the unit cost—r_1—times the pounds landed—Y.

With the costs separated into these components, the total cost (C_p) increases proportionally less than effort rather than more. If the yield function exhibits the expected diminishing returns to effort, then C_y must increase at a decreasing rate requiring C_p to do so also.

Extending the analysis to distribution of rent from the resource, E' catch in figure 1 indicates equilibrium for the open access resource and is the point where rent to the resource is zero. It is arbitrarily assumed that members receive their opportunity cost or wage at catch level E'. This is done for comparison purposes since in reality their real opportunity cost is not known. Therefore, to the left of E', in figure 1, part of the difference between C_p and C is rent accruing to crew members. To maximize rent to the fishery, rent to both vessel owners and crew members must be considered.

As the industry reduces effort below E', fewer crew members are needed in the industry. In traditional fishery economics, it is implicitly assumed that excess labor competes for limited crew member positions causing rent to crew members to be reduced and hence accrue to vessel owners. This effect is a downward shift in C_p curve of figure 1. However, if crew members, through unions or by long historical precedent, consider a fixed percentage share as the minimum they would work for as fishermen,[3] and if the time horizon to reduce effort from E' to E^* is several years, then C_p shifts little or none (Crutchfield and Zellner). For this analysis it is assumed that

[3] For example, in the last two years the Gulf shrimp industry has been caught in a severe cost-price squeeze. Attempts have been made to reduce the share agreement by having crew members share in the fuel cost. Even with some vessels remaining in port because they cannot meet variable cost, vessel owners have not been able to change the share agreement.

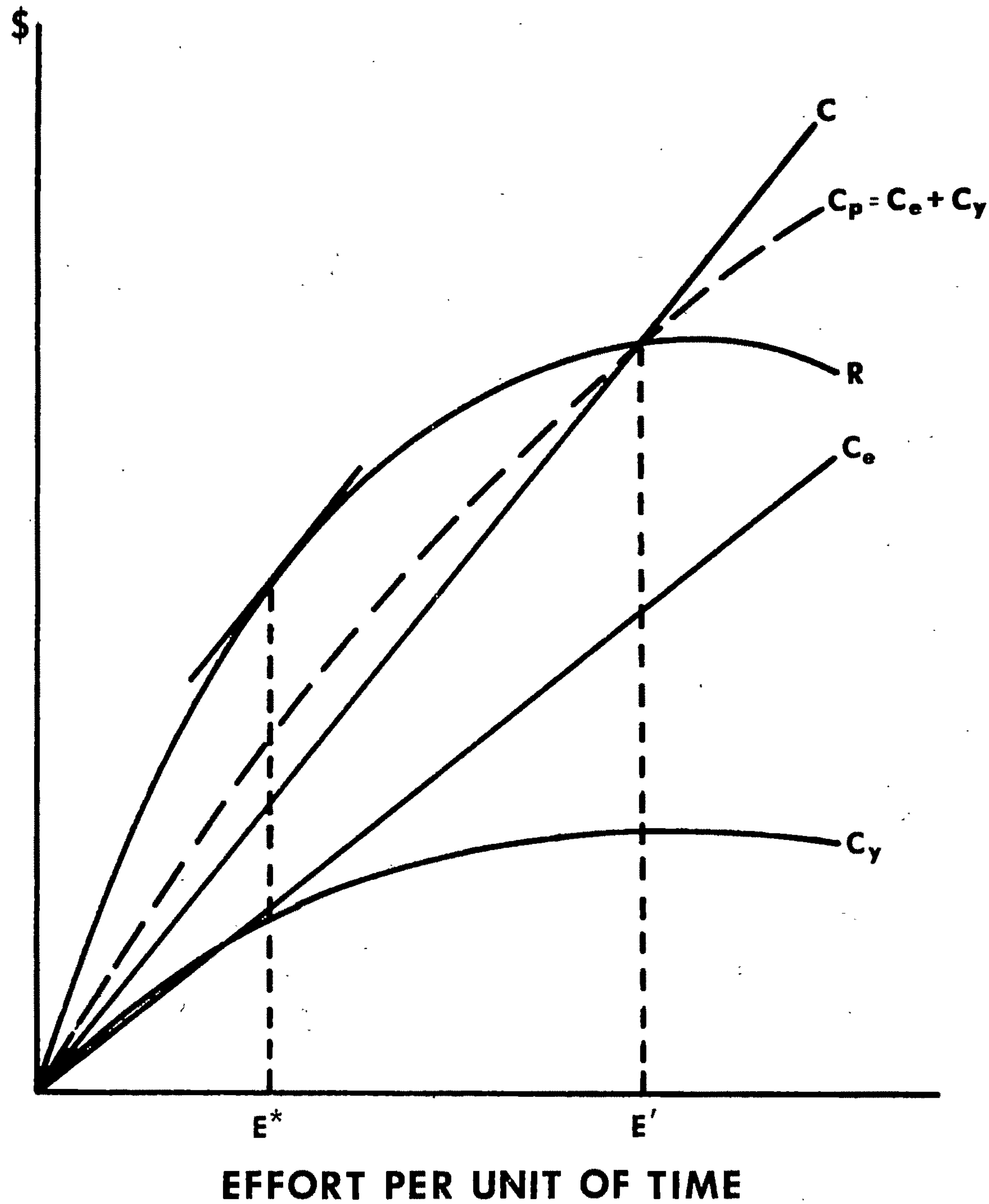

Figure 1. Hypothetical revenue curve (R) and cost curves when all cost items are proportional to effort (C) and when part of the cost items are proportional to effort (C_e) and part are proportional to catch (C_y)

crew share (as a percentage of catch) is fixed over time.

At equilibrium under open access fisheries (E'), the total revenue allocated to crew members (R_c) is equal to their opportunity cost (wage) plus production costs that are proportional to catch that crew members pay out of their share of catch, e.g., the crew may incur the cost of packing and handling of their share of the catch. However, as effort is reduced to

the left of E', it is expected that the number of crewmen is reduced proportionally to effort, while catch is reduced less than proportional to effort. This suggests crew members receive income above their opportunity cost and their part of production cost. This additional income to remaining crew members is rent from the resource. Thus, shares paid to crew members can be further disaggregated as follows:

$$(5)\ R_c = C_o + C_c + \Pi_c = r_2E + r_3sY + \Pi_c,$$

where C_o is opportunity cost of all crew members in the fishery and is calculated as the opportunity cost of the individual crew member association with each unit of effort—r_2—times total effort—E; C_c is production cost incurred by crew members that is proportional to catch and is calculated as the unit cost—r_3—times their share of catch—sY;[4] Π_c is rent accruing to crew members in the industry.

This provides the basic relationships needed to develop a model for estimating that level of effort that maximizes rent to the resource. To simplify to a single rent equation, equation (5) is substituted into equation (4) and then equation (4) into equation (3) to give the following relationship:

$$(6)\ \Pi_v + \Pi_c = R - C_e - C_o - C_c - C^*_v.$$

Since the objective is to estimate an optimum level of effort, it is necessary to express the right-hand side of equation (6) in terms of effort and catch. This gives

$$(7)\ \Pi_v + \Pi_c = PY - r_4E - r_2E - r_3sY - r_1Y,$$

where $C_e = r_4E$. Finally substituting the yield equation into equation (7), rent is maximized to the fishery by employing that amount of effort such that

$$(8)\qquad f'(E) = \frac{r_4 + r_2}{P - (r_3s - r_1)}.$$

This may be at an effort level less than, equal to, or greater than the effort level that maximizes rent to the resource using traditional analysis.[5]

[4] A more general model is one where crew members incur costs that are proportional to catch and effort; that is, instead of receiving a share of gross revenue, they receive a share of income above variable cost.

[5] Comparing equations (2) and (8), $r/P \gtreqless (r_4 + r_2)/(P - (r_3s - r_1))$ since $r_1 \gtreqless 0$, $r_2 > 0$, $r_3 > 0$, $r_4 > 0$, and $s > 0$. So $P > r_3s - r_1$, and $r = r_4 + sP\ Y_o/E_o + r_1\ Y_o/E_o$ and $r_2 \geq sP\ Y_o/E_o$ implies that $r > r_4 + r_2$, where E_o is actual effort exerted by the industry in a given year under open access, and Y_o is estimated catch based on the yield function associated with E_o. It can also be shown that rent is not necessarily maximized to vessel owners or crew members at the same effort level that maximizes rent for the resource.

Empirical Results

The methodology developed above was applied to the Gulf of Mexico shrimp industry. Optimum effort, catch, and rent are compared under traditional theory and under the proportional method as developed above.

The Yield Function

The topic of population dynamics is well documented in the literature cited earlier. However, the expected shape of the yield function needs to be discussed as it relates to this analysis. In most fisheries, the yield function is affected by both stock and crowding externalities. While the Gulf of Mexico shrimp fishery does experience crowding externalities, it does not experience the stock externalities since shrimp is an annual crop; that is, shrimp spawn offshore and the tide moves the larvae inshore to the estuaries. They grow into young shrimp and then move offshore to grow to maturity. Since laws protect the estuaries while the shrimp are young and since there is adequate natural protection offshore, fishing effort does not affect the recruitment stock relationship. Thus, assuming a constant population from year to year, as effort is increased, catch approaches some annual maximum yield (Schaefer).

However, the natural environment in the estuaries has a significant effect on annual shrimp production. Barrett and Gillespie have shown that temperature and salinities of bays and estuaries are important factors affecting the production of shrimp. High river discharge during the period that shrimp are in their nursery grounds reduces the temperature and salinity, causing population and, in turn, catch to be reduced. Therefore, the Mississippi River discharge (D), during the months that shrimp are in their nursery grounds, is included in the analysis.

With the existence of these conditions, the following yield relationship is used:

$$(11)\qquad Y = b_0D^{b_2}[1.0 - (b_1)^E],$$

where $b_0D^{b_2}$ is the maximum yield the function approaches for a given level of river discharge—D—(U.S. Army Corps of Engineers), and b_1 indicates the ratio by which marginal products of E decline. This Spillman-type function seems to be ideally suited to the physical relationship exemplified by Gulf shrimp fisheries (Heady and Dillon).

The catch-effort data used to estimate this relationship were developed from individual vessel records collected by the National Marine Fisheries Service for the period 1962–74 (U.S. Dep. of Commerce, 1962–74). Catch is total pounds (heads off) landed by all vessels in the Gulf of Mexico, and total effort is measured by days fished standardized by the relative fishing power of the individual vessels.[6]

Equation (11) was estimated using regression analysis and time-series data for the period 1962–74 as follows:[7]

$$(12) \quad Y = 3365D^{-0.5064}[1.0 - 0.994746^{E}],$$

where Y is in million pounds and E is in thousand units.[8]

Using average daily river discharge of 696 cubic feet per second, the maximum yield for vessels in the shrimp fishery is estimated to be 122.3 million pounds annually. Generally, effort has increased 50% (200,000 to 300,000 units) over the period 1962–74. Expected catch has increased 22% (79.7 million to 97.1 million pounds). The elasticity of production at 200,000 units of effort is 0.63% and at 300,000 units of effort is 0.40%. This implies that vessel owners are harvesting 37% less shrimp for each unit of effort exerted in the early 1970s than they were in the early 1960s. Furthermore, the production function suggests that if the vessel fleet were doubled so that it could exert 600,000 units of effort per year, expected catch would increase to only 117 million pounds or 20%.

Cost of Production

Cost data used in this study were collected for 115 vessels by personal interview of vessel owners and/or managers operating out of ports in Florida, Mississippi, and Texas for the calendar year 1973 (Wardlaw and Griffin). Costs proportional to catch are crew shares, payroll taxes, and packing charges.[9] Cost items proportional to effort are separated into the following categories: ice; fuel; nets, supplies, and groceries; repair and maintenance; insurance; depreciation; and opportunity costs on the vessel owner's capital investment.[10]

Since the Gulf shrimp fleet is comprised of a wide range in vessel size, construction, power, and capability, and there is a wide range of costs associated with the various vessel configurations, vessels are divided into nine different classifications based on construction, keel length, and effort index (table 1).

Total Cost for the Industry

Total cost proportional to effort (C_e) expended by all vessels in the Gulf is calculated from table 1 as follows:

$$(13) \qquad C_e = \sum_{i=1}^{n} N_i(C_{ei}),$$

where N_i is the number of vessels in class i operating in the Gulf in 1973 and C_{ei} is the total cost proportional to effort in class i.[11] In 1973 C_e was estimated to be \$122,383,000. Also, total effort exerted by all vessels in the Gulf in 1973 was estimated to be 304,431 units.[12] Therefore, from equation (8), r_4 = \$402,006 per thousand units of effort exerted in the Gulf in 1973.

Total costs proportional to catch incurred by all vessel owners in the industry, other than

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[6] Effort (E) was calculated in the Gulf of Mexico shrimp fishery as

$$E = \sum_{i=1}^{N} (EI_i)(DF_i),$$

where DF_i is the total days fished of vessel i, and EI_i is the effort index of vessel i (or relative fishing power) and is defined as the ratio of the catch per unit of fishing time of a vessel to that of a standard vessel, fishing on the same density of fish on the same type of ground. The value for the effort index for each vessel was calculated as $EI_i = [(HP)_i^{0.1384}\ (LFR)_i^{0.4064}]/[(38)^{0.1383}\ (14.6)^{0.4064}]$, where HP is the horsepower of vessel i, and LFR is the sum of the lengths of the footrope measured in yards for vessel i. The smallest class of vessels operating in the Gulf from 1962–71 was used as a standard with average horsepower of 38 and average net size measured in yards of footrope was 14.6 yards (Griffin, Cross, and Nichols).

[7] Because of the regression technique used, the actual equation estimated was $Y = b_0D^{b_2}[1.0 - b_1^{E}]^{a}$. Theoretically, $a = 1$; therefore, b_1 was solved for through an iterative procedure such that a approaches one.

[8] The student t-value for the regression coefficients b_0 and b_2 are 2.48 and −3.90, respectively; R^2 = 0.66 and the Durbin-Watson coefficient was 2.22.

[9] Share agreements are based on 35% of gross revenue, payroll tax rate is 7%, and packing is \$0.08 per pound for owner share of catch.

[10] Depreciation is calculated using the declining balance method used by the U.S. Department of Agriculture, and opportunity cost is calculated using a 9% interest rate.

[11] Latest data available on vessel characteristics are for 1971 (U.S. Dep. of Commerce 1971). These also are used to establish the distribution of vessel by class. Vessel cost data are available for 1973; hence, it is assumed that the relative number of vessels in each class did not change from 1971 to 1973.

[12] Effort is calculated by multiplying the index of effort of each individual vessel by days fished for that vessel in each class and then aggregating all vessels.

Table 1. Gulf Shrimp Vessel Costs by Class, 1973

Class No.[a]	Construction	Keel Length (Feet)	Effort Index (Units)	Number of Vessels in Each Class[b]	Cost Proportional to Effort per Vessel—Ce_i ($)[c]
1	Wood	45–62[d]	1.64–1.89	1,648	23,987
2	Wood	45–62	1.90–2.19	363	34,922
3	Wood	63–69	1.64–1.89	343	34,327
4	Wood	63–69	1.90–2.19	318	42,604
5	Wood	63–69	2.20–2.51	42	47,988
6	Steel	63–69	1.90–2.19	318	54,388
7	Steel	63–69	2.20–2.51	42	48,372
8	Steel	70–78	1.90–2.19	238	64,181
9	Steel	70–78	2.20–2.51	136	60,558
				3,448	

[a] See footnote 11 in text.
[b] This is the total number of vessels in the Gulf shrimp fleet in 1973.
[c] Costs are based on a sample of 115 Gulf shrimp vessels.
[d] Keel length of 45 feet was the smallest vessel in the sample of 115 from which cost data were obtained. Actually two-thirds of the 1,648 vessels in this class were less than 45 feet in keel length causing $23,987 to be an upward bias for this class.[j]

crew shares, include packing and handling charges and payroll taxes on crew shares and are calculated as

$$C^*_y = k(1 - s)Y + tsPY = [k(1 - s) + tsP]Y = r_1 Y, \tag{14}$$

where s is the share received by the crew, t is the payroll tax, and k is the average packing charge in pounds landed. For the Gulf shrimp fishery, $s = 0.35$, $t = 0.07$, and $k = \$80{,}000$ per million pounds landed; therefore, $r_1 = \$52{,}000 + 0.0245P$ (where P is now in price per million pounds).

In the earlier theoretical section it was assumed that crew members received their opportunity cost at equilibrium under open access E' in figure 1. Although this analysis is based on 1973 data when the industry may not have been in equilibrium, crew members' opportunity cost is arbitrarily assumed to be equal to their 1973 expected share minus their costs that are proportional to catch. Opportunity costs of all crew members in the fishery are calculated as

$$C_o = \left[sP\frac{Y_o}{E_o} - ks\frac{Y_o}{E_o}\right]E = r_2 E, \tag{15}$$

where $E_o = 304{,}431$ units and is the total effort exerted by all shrimp vessels in the Gulf in 1973 and $Y_o = 97.7$ million pounds and is the estimated production using the yield function in equation (12). Thus, $r_2 = 0.1123P - 8{,}986$.

Costs proportional to catch that are incurred by crew members include packing and handling charges paid on their share of revenue above their opportunity cost and are calculated as

$$C_c = ksY = r_3 sY. \tag{16}$$

Thus, $r_3 = \$80{,}000$.

Rent equation (8), which allows part of the cost to be proportional to catch and assumes that crew shares are a fixed percentage of gross revenue, can now be written as

$$\Pi_v + \Pi_c = PY - 402{,}006E - (-0.1123P - 8986)E - 28{,}000Y - (52{,}000 + 0.0245P)Y = (0.9755P - 80{,}000)Y + (-0.1123P - 393{,}038)E. \tag{17}$$

With estimates of r_1, r_2, r_3, and r_4, the value of the unit cost of effort (r) is determined from equations (4) and (5) by applying the traditional method in equation (2) as

$$rE_o = r_4 E_o + sPY_o + r_1 Y_o. \tag{18}$$

Solving for r and substituting in known values, $r = 418{,}694 + 0.1202P$. The traditional rent equation (2) can be written as $\Pi_t = PY - (418{,}694 + 0.1202P)E$.

Equilibrium in the Fishery

Using the traditional methodology and the technique that allows some cost components to be proportional to catch, table 2 shows the economic optimum effort level in the Gulf shrimp fishery with associated catch, number of vessels, maximum rent, equilibrium effort

Table 2. Effort, Catch, Vessels, and Rent(s), Gulf of Mexico, 1973.

	Price/Pound		
Item	1.40	1.70	2.00
Maximize rents			
Optimum effort (1000 units)			
Traditional	81.6	107.1	127.3
Proportional	77.6	105.3	126.9
Estimated catch (mil. lbs.)			
Traditional	42.7	52.7	59.7
Proportional	41.0	52.1	59.6
Number of vessels			
Traditional	924	1,213	1,441
Proportional	879	1,192	1,438
Maximum rent (mil. $)			
Traditional	11.9	22.9	35.6
Proportional	10.8	21.6	34.3
Owner	2.6	10.3	20.5
Crew	8.2	11.3	13.8
Equilibrium under open access			
Effort (1000 units)			
Traditional	177.0	239.0	291
Proportional	111.0	201.0	282
Estimated catch (mil. lbs.)			
Traditional	74.2	87.6	96.9
Proportional	54.2	79.9	94.6
Number of vessels			
Traditional	2,005	2,707	3,296
Proportional	1,257	2,277	3,194
Rent to crew member (mil. $)			

employed, and number of vessels assuming open access at three different price levels. The average exvessel price for shrimp received by vessel owners in 1973 was approximately $1.70 per pound.

Under open access, the estimated equilibrium amount of effort that vessel owners expend annually in harvesting shrimp from the Gulf of Mexico is 239,000 units using the traditional method and 201,000 units using the proportional method (table 2). Using the proportional method, equilibrium under open access is the same point where $R = C_p$ (or vessel owner's rent is zero) in figure 1. However, opportunity cost to crew members was calculated at the level of effort exerted in 1973 (304,431 units). Therefore, since equilibrium under open access using the proportional method is less than 304,431 units of effort, rents accrue to crew members in the amount of $8.7 million (table 2). Rent to crew members would be negative for the other case.

Equilibrium values for both the traditional and proportional method under open access are below the amount of effort actually expended in 1973 (304,431 units). One reason for this is the dramatic increase in the price of fuel and related products in the last quarter of 1973, which increased the cost of harvesting shrimp. Another reason is all vessels that landed shrimp in the Gulf in 1973 were assumed to be full-time shrimp vessels. Some vessels may have fished only part of the year because they were bought or sold some time during the year, or they may have been used in other fisheries part of the year.

Economic Optimum

With the continuing interest in maximizing rent to open access resources, these results are important, particularly with respect to distribution of rent between vessel owners and crew. Serious implications evolve relative to an appropriate policy for maximizing rent to the resource that is not included in previous analysis. The optimum effort that maximizes rent to the fishery is 107,100 units using the traditional method and 105,300 units using the proportional cost method.[13] Associated with the estimated optimum effort based on traditional theory are 1,213 vessels, assuming the same distribution among vessel classes, harvesting shrimp worth $22.9 million in rent to the resource. Using the proportional method, 1,192 vessels harvest shrimp returning a rent of $21.6 million of which $10.3 million accrues to the vessel owners and $11.3 million accrues to the crew members. Hence, the traditional method overestimates the optimum units of effort by only 1800 units (1.7%) but overestimates the rent accruing to the vessel owner by $12.6 million (122%). It is this discrepancy inherent in traditional analysis that is of special concern.

This distribution aspect of rent to vessel owners and crew members has important implications for fishery management schemes. If, for example, a government imposes a limited entry scheme taxing (through license or other means) vessel owners remaining in the industry at an amount equal to $22.9 million, vessel owners are overtaxed by $12.6 million. The actual tax rate should be $21.6 million and should be shared by vessel owners and crew members. Vessel owners in the shrimp industry should pay a total tax of $10.3 million, where crew members should pay a tax of $11.3 million. This is a tax on owners of $8,641 per vessel and $9,480 tax per crew.

This provides implications based on 1973.

[13] This optimum level of effort is beyond the range of the data used to estimate the yield function.

However, the analysis is sensitive to product price and fishing costs. Considering just price changes, they have a definite impact on the distribution of rent to vessel owners and crew members (holding unit cost constant). When prices increase from $1.70 to $2.00 per pound of shrimp landed, total rent to the resource increases to $34.3 million. Of this, vessel owners receive $20.5 million, which is a 100% increase in their total rent. However, since more vessels are employed, rent on a per vessel basis increases from $8,641 to $14,256 or an increase of 65%. Crew members receive $13.8 million, a 22% increase, while rent per crew increases only 1% from $9,480 to $9,564.

When prices decrease from $1.70 to $1.40 per pound of shrimp landed, as they did from 1973 to 1974, total rent decreases to $10.8 million to the resource. Of this, vessel owners receive only $2.6 million, which is a 75% decrease. This dropped 65% per vessel from $8,641 to $2,958. Crew members received $8.2 million, which is a 27% decrease. Per crew, there was only a slight decrease of less than 2% from $9,480 to $9,330.

Conclusions

This study emphasizes the distortions that exist in applying traditional methods to estimate fishing effort that maximizes rent to an open access resource when some of the costs are proportional to catch. This distortion, if used in developing fishing management schemes, could result in significantly misplaced controls, i.e., an overtaxing of vessels and ignoring rent accruing to crew members. The effect could result in a fishery being grossly mishandled and misused.

Application of the model developed shows that management schemes must be dynamic if they are going to be effective, since optimum effort rent to the resource is very sensitive to price changes. This means rent to vessel owners on a per vessel basis is very sensitive to product price changes. However, when crews receive a fixed share of gross revenue and do not share in the other cost proportional to effort, rent per crew member is affected only slightly at optimum effort due to price change. If crew members share in some of the cost proportional to effort, their rent per crew member is more sensitive.

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A Spatial Equilibrium Analysis of Electrical Energy Pricing and Allocation

Noel D. Uri

Based upon a spatial equilibrium model, this study argues that society can gain with increased regional coordination of generation and transmission activities of the U.S. electrical energy industry. In 1973 society suffered a loss in welfare because of minimal regional coordination, reflecting that consumers in regions where relatively inexpensive electrical energy was available were permitted to consume more and pay less than what would have been optimal at the expense of consumers in less efficient producing regions. The policy implications suggest that regional coordination be more actively pursued, involving the use of legislated authority by the Federal Power Commission.

Key words: electrical energy, spatial equilibrium analysis, United States.

Historically, decisions on the pricing and allocation of electrical energy have been made according to legal and administrative criteria. When electrical energy was plentiful (in relation to price), few questions were raised concerning efficiency in the electrical energy industry. Recent years, however, have witnessed a growing realization of the need for improvements in the operational efficiency of the industry. This has challenged economists to investigate and develop methodologies that would allow normative recommendations to be made about pricing and allocation.

The purpose of this article is to demonstrate that the interregional equilibrium model developed by Samuelson and by Takayama and Judge (1964) may be adapted to determine the efficient pricing and allocation of electrical energy in the United States. In the present instance, it is assumed that the authority responsible for the pricing and allocation decisions does not act as a profit-maximizing monopolist but rather seeks a policy that will ensure that social welfare in relation to the available electrical energy is maximized.

The basis for this assumption is well grounded. The Federal Power Act of 1935 directed the Federal Power Commission to promote and encourage "the voluntary interconnection and coordination of facilities for generation, transmission and sale of electric energy" in order to "assure supply of electrical energy throughout the United States with the greatest possible economy with regard to proper utilization and conservation of natural resources" (Federal Power Commission 1970, pp. 33–34).

That this regional coordination is technically feasible has been adequately documented (National Electric Reliability Council 1975b). That it is economically attractive is also true. Among the economic arguments put forward to support regional coordination is that such coordination allows joint planning and operation of facilities, makes the exchange of economy energy easier,[1] prevents construction of unnecessary facilities by isolated systems, and increases reliability. More specifically, as a result of transmission interties, coordination offers distinct economies to participating systems. Because of time-of-day diversities (and the noncoincidental occurrence of the peaks of participating systems), it might be possible to reduce the total generating

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[1] Economy energy is defined as energy produced and supplied from a more economical source in one system, substituted for that being produced or capable of being produced by a less economical source in another system.

capacity requirements that otherwise would apply were each system charged with fully meeting its needs. By combining the existing capacity of many utilities, it is possible to reduce the needed reserve capacity.

Unfortunately, this coordination is still seriously inadequate (Breyer and MacAvoy). Why are not coordination arrangements actively pursued? There seems to be no straightforward answer. One of the problems seems to be that of dividing the potential gains from coordination among partially regulated companies. Another is that competition and regulation have combined to dampen the firms' desire to achieve coordination economies. The fact that a pool's method for apportioning operating costs is not likely to maximize incentive for its members to operate the whole system most efficiently presents another problem. Finally, if utilities coordinate their plans on a regional level, some generating plants might conceivably be constructed in areas that do not need electrical energy but are relatively inexpensive sites for large generating plants. The residents of areas subject to this risk justifiably may not want to have plants built to supply consumers in other areas.

No objective model can provide solutions to some of these problems. Conflicts among competing consumers and producers inevitably continue, and politics, rather than economics, is the final arbiter in the solution. The areas of conflict may be narrowed, however, and better choices may result if clear statements about equilibrium prices and the resulting allocation of electrical energy among competing consumers are available. This is the objective here.

Framework of Analysis

A spatial equilibrium model of production, consumption, prices, and transmission is constructed to represent the market for electrical energy in the United States. The basic model is that developed by Samuelson in 1952 and generalized by Takayama and Judge in 1964 and by Takayama and Woodland in 1970. The general model is adapted to accommodate the peculiarities of the market for electrical energy.

The objective of the study is to determine the optimal allocation and pricing of electrical energy for a given period for the contiguous United States. Consequently, the demand and supply equations and transmission costs are estimated and then used to determine the most efficient allocation for an arbitrarily (though not capriciously) chosen year—1973. The model is not cast in a general equilibrium framework. Other markets are considered to be outside of the investigation. Therefore, when discussing optimality it is in a partial equilibrium setting with the resultant qualifications necessary for the meaning of optimality.

The determination of the optimal allocation and pricing is accomplished by maximizing the net social payoff of the United States.[2] Before specifying the model, it is convenient to introduce the needed definitions and notation. Let $i, j = 1, 2, \ldots, R$ denote the regions, $\theta = 1, 2, \ldots, P$ denote the plant type for generating electrical energy (e.g., hydroelectric, nuclear), y_i is the quantity of electrical energy demanded by consumers in region i, x_{ij} is the quantity of electrical energy transmitted and distributed from region i to region j, x_i^θ is the net quantity of electrical energy generated in region i by plant type θ, K_i^θ is the generating capacity of plant type θ in region i, and t_{ij} is the unit cost of transmitting and distributing electrical energy from region i to region j.

Assuming that demand functions in each region are known with certainty or are available in the certainty equivalence sense, the demand functions are given as

$$(1) \qquad p_i = f_i(y_i),$$

where p_i is the price of electrical energy to all consumers in region i. A single demand function is used aggregated across all consumers in a region. The implications of this assumption are discussed by Mohring.[3]

Similarly, assume the cost functions are known with certainty or are available in the certainty sense. The marginal operation and

[2] Net social payoff in terms of the underlying demand and supply relations for all regions is defined as follows: the sum of the areas under the demand functions minus the sum of the areas under the supply functions at posttrade equilibrium prices, the sum of the areas under the supply functions at pretrade prices, and the total transmission and distribution costs incurred. Because the sum of the areas under the demand functions minus the sum of the areas under the supply functions at pretrade prices is constant, the sum may be omitted from the definition without altering the posttrade prices and allocation.

[3] Mohring argues that for the demand price of a commodity to depend only on its output level requires that a utility function u (perhaps after suitable transformation) can be written in the form $u = y_1 + \sum_{j=2}^{n} f^j(y_j)$, where f^j denotes the inverse demand function for commodity j and the y_j's are the units of the n commodities (p. 694).

maintenance cost functions (including fuel cost) are given by

(2) $$\Omega_i^\theta = \omega_i^\theta (x_i^\theta),$$

where Ω_i^θ is the marginal cost of generation per kilowatt-hour on plant type θ in region i. Marginal cost functions per unit capacity (capital cost) are given by

(3) $$\Gamma_i^\theta = \gamma_i^\theta (x_i^\theta),$$

where Γ_i^θ is the marginal capital cost per kilowatt-hour generated on plant type θ in region i.

The search for optimum demands, prices, and operating schedules is subject to a number of constraints. For a given region the quantity of electrical energy demanded must be less than or equal to the quantity supplied by that region plus the quantity transmitted from other regions:

(4) $$y_i \leq \sum_j x_{ji}.$$

For each region the total net transmission and distribution of electrical energy is less than or equal to the net generation from all plant types within that region:

(5) $$\sum_j x_{ij} \leq \sum_\theta x_i^\theta.$$

Transmission of electrical energy between regions is less than or equal to the maximum capacity of transmission lines available:

(6) $$x_{ij} \leq x^*_{ij},$$

where x^*_{ij} is the maximum technologically feasible interregional transmission. For each plant type in a region, net generation is less than or equal to the net generating capacity available for that plant type:

(7) $$x_i^\theta \leq K_i^\theta.$$

Pricing and Allocation Model of Electrical Energy

Before delineating the spatial equilibrium model, observe that in the formulation to follow it is desired to maximize the United States' welfare as a whole. Consequently, unrestricted transmission is optimal in the sense that it leads to the nation's welfare frontier conditional upon other factors being in equilibrium.

Using the notation and constraints as defined, the Hotelling type of net social welfare function that forms the objective function of the problem may be characterized as

(8) $$NSP = \sum_i \int f_i(y_i)\, dy_i - \sum_i \sum_\theta \int \omega_i^\theta (x_i^\theta)\, dx_i^\theta - \sum_i \sum_\theta \int \gamma_i^\theta (x_i^\theta)\, dx_i^\theta - \sum_i \sum_j t_{ij} x_{ij},$$

where NSP nominally refers to net social payoff.

Assuming the objective function is concave, the Kuhn-Tucker conditions give the necessary and sufficient conditions for the competitive solution (Takayama and Judge 1971). Associate the dual variables, ρ_{1i}, ρ_{2i}, ρ_{3ij}, and ρ_{4i}, with constraints (4) through (7), respectively.

The variable ρ_{4i} can be interpreted as the quasi-rent of plant type θ in region i and, if that plant type is utilized, is equal to the supply price ρ_{2i} minus the marginal operation and maintenance (here after operating) cost plus capital cost. Both operating cost and capital cost are used to determine the supply price. Unlike a peak-load pricing approach (Turvey), a utility is allowed to recover part of its capital cost (as well as a specified rate of return) on each kilowatt-hour of electrical energy generated (Jurewitz).

The Kuhn-Tucker conditions guarantee that to minimize total cost production will be scheduled on plant types in increasing order of supply and delivery costs. Therefore, the demand price to a consumer in a region equals the transmission and distribution costs plus the operating and capital costs on the least efficient plant type being used to generate electrical energy.

The quasi-rent of any plant type regardless of region in use is equal to the difference between its operating cost plus capital cost, distribution cost, and transmission cost and these costs accounted for by the least efficient plant type in all regions. Given this condition, it is possible to use a plant type to generate electrical energy that does not have the lowest combined operating and capital cost. If the transmission cost, say, is sufficiently large, then it might be optimal to use a plant with a higher operating or capital cost component while shutting down a plant type that is more efficient.

The model in the present formulation can answer the pricing and allocation questions that have tended to mitigate the desire for regional coordination among electric utilities. Specifically, the model indicates such things as how to apportion operating costs (by the

Table 1. Regional Classification

Region	State Composition
New England (NE)	Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut
Middle Atlantic (MA)	New York, New Jersey, Pennsylvania
East North Central (ENC)	Ohio, Indiana, Illinois, Michigan, Wisconsin
West North Central (WNC)	Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas
South Atlantic (SA)	Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida
East South Central (ESC)	Kentucky, Tennessee, Alabama, Mississippi
West South Central (WSC)	Arkansas, Louisiana, Oklahoma, Texas
Mountain (M)	Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada
Pacific (P)	Washington, Oregon, California

region in which they occur). It cannot, and no model can, solve the problems concerning the institutional aspects that create the lack of desire for coordination. What this model can show is, by expanding the area of concern to encompass the country, the extent to which all of society will be better off even though some regions may be worse off.

The Setting

Before turning to the 1973 empirical implementation of the model, the various regions and plant types considered are discussed and the demand and supply estimates are presented. The regional classification used is the Bureau of the Census's nine-region division of the contiguous United States and can be found in table 1.

On the supply side, three alternative plant types for generating electrical energy are considered. They consist of hydroelectric plants, fossil-fueled steam electric plants (coal, oil, and natural gas), and nuclear steam plants. Internal combustion, a fourth method of generating electrical energy, is not considered. It accounted for only 0.33% of net generation in 1973.

Demand and Supply Estimates

Following Takayama and Judge (1964), it is assumed here that the demand and supply functions are known linear price-dependent relations. This reduces the general objective function (6) to a quadratic function, and hence one is confronted with a quadratic programming problem. This is done because of the availability of computer programs to handle very large quadratic programs. Some loss is incurred in making the linearity assumptions, as they are probably relevant in the short run but certainly not in the long run. Consequently, the analysis is confined to the short run exclusively.

Various econometric problems arise in estimating the demand curves for electrical energy (Uri 1975). Therefore, the linear demand curves are obtained first by estimating the price elasticity and then by converting these elasticities into point estimates of the aggregate demand functions. To estimate the demand elasticity for each region, a variable elasticity model analogous to the one used by Mount, Chapman, and Tyrrell is specified. Specifically, the quantity of electrical energy consumed in a region in a given year is assumed to be a function of the quantity of electrical energy consumed in the previous year, the average price of electrical energy for that year, per capita personal income for that year, and the average price of natural gas in the previous year. Upon pooling cross section and time series across all regions for the time period 1946–73, the price elasticities are estimated. Regionally, they range between −0.123 and −0.197 in the short run, which is within the range of the short-run elasticities obtained by Mount, Chapman, and Tyrrell as well as the values obtained by others (see Taylor).[4]

Other types of problems arise when trying to estimate the marginal operating and marginal capital cost. One such problem is that capital cost falls as capacity increases. This prob-

[4] Mount, Chapman, and Tyrrell get short-run elasticity estimates of about −0.14 for the residential sector, −0.20 for the commercial sector, and −0.20 for the industrial sector.

lem is suppressed by limiting the analysis to the short run. With the focus on the short run, and because of data problems, the assumption that marginal and average costs are equal is made.

Thus, average annual production expenses for the various plant types in the various regions are assumed to equal marginal operating costs. These production expenses are estimated for 1973 for a representative selection of plants in each region from the Forms Number 1 and 1-M filed by each utility with the Federal Power Commission.

Marginal capital costs are assumed to equal average capital costs. The average capital costs are estimated for a selection of plants in each region from Form 1159 filed by each utility with the Federal Power Commission. Given the kilowatt estimate, kilowatt-hour cost is calculated based on the service life of a particular plant type, the total net generation expected each year, the rate of equipment depreciation, and the annual rate of fixed charges that includes the cost of money, interim replacements, insurance and taxes, and a rate of return on investment.

Transmission cost is computed from average cost curve data found in the *1970 National Power Survey* by assuming a functional form of

$$T_{ij}/x_{ij} = a + b/x_{ij} + \epsilon_{ij}, \tag{9}$$

where a and b are coefficients, T_{ij} is the cost of transmitting a kilowatt-hour of electrical energy one mile, x_{ij} is as defined above, and ϵ_{ij} is the error term (Federal Power Commission 1971). The marginal cost of transmission (a) is estimated to be 0.00478 mills per mile.[5] A more complete description of the estimation process is contained in Uri (1976). Based on informal conversations with members of the electric utility industry, this figure is a realistic estimate of marginal transmission cost.

Nine demand points are used in the model for the purpose of measuring the distance between region i and region j. The resulting distance times the marginal cost of transmission will give the cost of transmitting one kilowatt-hour between region i and region j. The demand areas are large and it is difficult to select a single location as representative of an entire region. The method used to pick a representative location is to weigh each set of coordinates in a region by the consumption of electrical energy at that location, the average distance traveled by each kilowatt-hour through a region, and the maximum distance that electrical energy would have to travel.

Estimates of the maximum capacity of transmission lines between regions are obtained from the National Electric Reliability Council (NERC) (1975b). The NERC analysis included consideration of the effects of technical factors that are important. Such things as scheduled and nonscheduled maintenance, noncoincidence of peak load, the necessity of operating generating equipment for area protection and voltage control, and so on were included in the analysis.

Distribution cost is obtained from the *1970 National Power Survey* (inflated to account for price increases) and represents an average for all electric utilities in the contiguous United States. No attempt has been made to break the cost down by region, type of ownership, or other system of classification. Given the relatively low level of spatial resolution, regional averages closely approximate the national average and hence this value can be used without severe reservations. The figure used is 6.05 mills per kilowatt-hour.

Finally, the net generating capacity used reflects the actual net generation and hence consumption in 1973. It is obtained from the Edison Electric Institute.

As a final comment before turning to a solution for the model, all of the values of the primal variables in the problem are in net terms. Thus, for example, the quantity of electrical energy transmitted is in net terms and hence implicitly assumes that the same transmission loss is incurred for electrical energy transmitted interregionally as is transmitted intraregionally.

Empirical Results

In the current investigation, a policy is sought that will insure that net social payoff (social welfare) is maximized relative to the available supply of electrical energy. Economic theory indicates that such a situation is approached when a competitive market prevails. Under this condition, the market price of electrical energy should equal the marginal cost of supplying electrical energy to the market, which in turn is equal to the value in use of the last

[5] The marginal cost of transmitting a kilowatt-hour of electrical energy is

$$\frac{\partial T_{ij}}{\partial x_{ij}} = a.$$

Table 2. Optimal Flows of Electrical Energy Generated in 1973 by Region (Billion Kilowatt-Hours)

	To								
From	NE[a]	MA	ENC	WNC	SA	ESC	WSC	M	P
NE	68.36 (68.36)								
MA		104.46 (223.31)							
ENC		16.22 (0)	317.56 (333.78)						
WNC				92.48 (108.91)					
SA		81.46 (0)			224.79 (294.10)				
ESC		13.36 (0)				155.53 (168.89)			
WSC		19.73 (0)					175.89 (195.62)		
M				16.43 (0)				60.75 (77.18)	
P									222.55 (222.55)

Note: Values when transmission is restricted are in parentheses.
[a] The regional abbreviations denote the New England region, the Middle Atlantic region, and so on from table 1.

kilowatt-hour purchased by the consumer. This is exactly what the Kuhn-Tucker conditions for optimality guarantee.

Assuming that a competitive market prevails across plant types and regions, a solution to the spatial equilibrium model can be found. The optimal values are presented in tables 2 through 5. Not all of the values are presented. Specifically, supply prices are simply demand prices less distribution and transmission costs. In none of the cases where it is optimal to transmit electrical energy interregionally were the transmission constraints reached.

The solution gives overwhelming support to the argument that regional coordination of the generating activities of utilities results in significant interregional transfers of electrical energy with the bulk of the transmission activity taking place to the Middle Atlantic region from surrounding regions. This results because of the relatively older and consequently less efficient fossil fuel plants as well as, and most importantly, because of the high proportion of oil-fired plants that proved to be quite expensive to operate in 1973. In the short run it would have been optimal from the perspective of the whole society to let consumers in other regions bear some of the burden (through higher prices for electrical energy) of the high cost of electrical energy in the Middle Atlantic region. In the long run, it might be optimal to build new generating capacity. (The answer to such a question is outside the scope of the present study.)

A comparison of the competitive alternative with existing market behavior is apparent from table 4. The optimal prices differ by no more than transmission costs between regions where electrical energy interchange takes place. Predictably, the price to the consumer in the more efficient regions rises and in the less efficient regions falls.

The value of a particular plant type, measured by its quasi-rent, is presented in table 5. Hydroelectric plants are of greatest value to society with nuclear plants second in most regions. This suggests that if additional output could be obtained from existing plants by increasing the utilization factor through increased regional coordination, the gains to society in the aggregate would be even greater than those indicated here.[6] In this vein, the quasi-rents provide information about the types of plants on which it is most efficient to increase generation. By increasing the net generation by one kilowatt-hour on a fossil-fueled plant located in the South Atlantic region and transmitting it to the Middle Atlantic region and correspondingly decreasing the generation on a fossil-fueled plant in the Middle Atlantic region so that net additions to

[6] The utilization factor is the ratio of the actual output of a system to the maximum possible output. For the United States as a whole this is about 52%.

Table 3. Optimal Net Generation in 1973 (Billion Kilowatt-Hours)

Region	Hydroelectric Plants	Fossil Plants	Nuclear Plants
New England	4.93	50.19	13.24
	(4.93)	(50.19)	(13.24)
Middle Atlantic	27.81	66.36	10.29
	(27.81)	(185.21)	(10.29)
East North Central	3.55	301.67	26.56
	(3.55)	(301.67)	(26.56)
West North Central	11.36	77.56	3.56
	(11.36)	(93.99)	(3.56)
South Atlantic	17.79	272.00	16.31
	(17.79)	(260.00)	(16.31)
East South Central	24.92	143.72	0.25
	(24.92)	(143.72)	(0.25)
West South Central	9.02	186.60	0
	(9.02)	(186.60)	(0)
Mountain	25.74	51.44	0
	(25.74)	(51.44)	(0)
Pacific	124.25	91.79	6.51
	(124.25)	(91.79)	(6.51)

Note: Values when transmission is restricted are in parentheses. Actual net generation figures for 1973 are the same as the values when transmission was restricted with the exception that about 12 gigawatt-hours were generated in the South Atlantic region and transmitted to the Middle Atlantic region and about 8 gigawatt-hours were generated in the Mountain region and transmitted to the Pacific region in 1973. This additional generation occurred in all probability on fossil plants.

generation are zero, societal welfare would expand by 3.98 mills.

The implications of this are clear. Taking advantage of the noncoincidental occurrence of the peak demands of different utility systems across regions so that the more efficient plants are used to the exclusion of the less efficient plants is consistent with the social welfare maximization objective.

The optimal levels of generation are slightly different from actual levels on fossil plants in the Middle Atlantic and West North Central

Table 4. Price by Region for 1973 in Mills per Kilowatt-Hour

Region	Actual Price[a]	Optimal Price
New England	24.29	24.29
Middle Atlantic	25.10	23.94
East North Central	19.17	19.92
West North Central	21.01	20.15
South Atlantic	18.54	19.82
East South Central	12.55	19.27
West South Central	15.75	16.27
Mountain	16.96	17.25
Pacific	14.90	14.94

[a] Weighted average price by consumers according to the quantity of electrical energy demanded in 1973.

Table 5. Quasi-Rent of a Plant Type in Mills per Kilowatt-Hour in 1973

Region	Hydroelectric Plants	Fossil Plants	Nuclear Plants
New England	10.50	1.60	8.39
Middle Atlantic	11.98	0	6.79
East North Central	8.42	2.12	7.17
West North Central	5.50	3.08	4.85
South Atlantic	8.00	3.98	6.85
East South Central	8.69	5.41	5.76
West South Central	1.37	0.57	4.80
Mountain	2.62	0	4.82
Pacific	5.09	1.35	2.11

regions in 1973, arising due to higher operating costs of these plant types relative to costs in other regions from which electrical energy is transmitted. This change in the optimal level of generation in conjunction with the quasi-rents has significant implications since a great deal of public reaction to generating capacity additions results from the type of plant. By adding a nuclear plant comparable in cost respects to existing nuclear plants in, say, the West North Central region while at the same time retiring an "average" fossil plant, the net benefit to society would be 1.73 mills per kilowatt-hour. This excludes putting any pecuniary value on potential hazards from nuclear generation.

Incidentally, the positive nature of the quasi-rents on plant types within a region indicates a price in excess of recovering incurred costs plus a return on investment. In other words, the regulatory commissions set a price higher than warranted in 1973 in all regions except the Middle Atlantic and Mountain regions.

Restrictions on Interregional Transmission

As noted previously, regional coordination of electrical energy is not yet a normal part of the operation of the market for electrical energy.[7] In what follows, the costs to society arising from the lack of coordination are measured.

It has long been recognized that some trade (i.e., interregional transmission) is always potentially beneficial (Graaff). If one regards the

[7] The footnote on table 3 gives approximately the total interregional transmission. In the unrestricted model, electrical energy transmission into the Pacific region (specifically the Los Angeles area) from the Mountain region (the Four Corners power plant) does not show up because of the model structure.

entire United States as the group whose welfare it is desirable to maximize, unrestricted transmission leads to the nation's welfare frontier (subject to the aforementioned qualifications). If one is concerned with maximizing the welfare of a particular region, one would prefer movement along the frontier in a direction that favors the region with whom the concern rests. This is precisely what is done by restricting transmission by institutional means to and from a region. Thus, it is observed in what follows that the welfare of regions that have an economic advantage in the generation of electrical energy increases while the welfare of the less fortunate regions falls. In the aggregate society is worse off.

To quantitatively measure the impact of the lack of regional coordination, the constraint $x_{ij} = 0$ for $i \neq j$ is imposed on the spatial equilibrium model. Associated with this constraint will be a dual variable (ρ_{5ij}) that can be interpreted as the quasi-rent accruing to utilities in region i due to a restriction on the transmission of electrical energy to region j.

The results of imposing transmission restrictions can be found. These need not be enumerated because they can be obtained from a knowledge of the Kuhn-Tucker conditions and the solution for the unrestricted model. The equilibrium price of electrical energy, because of the way the demand curves are approximated, becomes the actual price observed in 1973. The quasi-rents arising from transmission restrictions are just the difference in the actual prices between regions. These quasi-rents are greater than estimated transmission costs between those regions where transmissions occurred, but in other regions a penalty due to the constraint is incurred, though this penalty does not indicate a strong enough desire on the part of consumers to have additional electrical energy. The quasi-rent for any plant type in a region is the difference between the actual price in 1973 and the operating and capital costs of that plant type.

The cost to society arising from the transmission restrictions is measured as the difference between the net social payoff in the restricted and unrestricted models. Quantitatively, this value is \$301 million. Thus, there is a real loss to society arising from uncoordinated generation by electric utilities in the United States.

The quantity of electrical energy generated does not change between solutions except in the Middle Atlantic region. The regions that have an economic advantage in the generation of electrical energy are able to supply the same quantity but at a lower price. This results in a larger intraregional consumption.

Obstacles to Coordination

As previously noted little electrical energy is transmitted interregionally. In 1973, only about 20 million kilowatt-hours (1% of total net generation) were transmitted interregionally. Given the significant gains that could have been made by transmitting electrical energy into the Middle Atlantic region in particular, a natural question is why was this not done. The general problems to coordination were alluded to above and basically revolve around the institutional structure.

With regard to the Middle Atlantic region, the specific arguments by utilities put forward against coordinated operation include (*a*) organizational complications, (*b*) larger area to be affected by system disturbances, and (*c*) complexity of operation (Federal Power Commission 1971). These problems are no different than those encountered by other regions. If only technological factors were to be considered, each of these problems could be mitigated. Unfortunately, it appears that the social climate is the militating force. One quote that typifies the industry attitude is "Interconnections cannot replace a long-term deficiency in installed generating plant or primary fuel supply. The purpose of interconnections is to permit the coordinated operation of generating capacity and for the transfer of power among systems at times of short-term emergencies" (NERC 1975a, p. 3).

Thus, it can be expected that without outside impetus the industry will continue to operate in the future as it has in the past—devoid of any active coordination efforts.

Sensitivity of the Results

While the model yields some interesting conclusions, the interpretations would be misleading if the results depended on the specific parameters used. The estimates of costs are by no means perfectly accurate. If slight changes in the estimates lead to major changes in conclusions, then the model is not at all interesting.

One of the estimates crucial to the empirical implementation of the model whose influence on the results is not immediately clear is the estimate of the price elasticity. It is well known that the omission of variables when specifying a demand equation will bias the estimates of ordinary least squares. Further, it should be apparent that some important variables have not been included in the demand equations used to estimate the price elasticities. Consequently, the model was solved both with and without transmission restrictions where it is assumed that the true price elasticity is both twice and one half of the estimated value. In both situations, the results do not change significantly.

The other estimates of great importance are transmission costs. These were varied in additional solutions to the unrestricted model. The interregional transmissions continued to obtain as long as it was assumed that actual transmission costs were less than the price differentials between regions.

A reduction of transmission cost estimates by 50% results in additional transmission from the East South Central region to the New England region. An increase in transmission cost estimates by 50% eliminates interregional transmission only between the East North Central and Middle Atlantic regions, the West South Central and Middle Atlantic regions, and the Mountain and West North Central regions. The gains to society from interregional coordination even in this latter case are still significant.

Conclusions and Their Policy Implications

The major conclusion that results from the foregoing analysis is that society can gain with increased regional coordination of the generation and transmission activities of the electrical energy industry in the United States. Using 1973 as a point of reference, the study indicates that society suffered a loss of $301 million in social welfare (i.e., net social payoff) because of minimal regional coordination. This reflected the fact that consumers in regions where relatively inexpensive electrical energy was available were permitted to consume more and pay less than what would have been optimal from a total societal perspective at the expense of consumers in less efficient producing regions.

Given the conclusions, the policy implications suggest that regional coordination be more actively pursued. The mechanism of this pursuit is suggested here. Coordination agreements, because of their nature, must be filed with the Federal Power Commission, which has authority to examine the propriety of the details and make appropriate modifications. The Federal Power Act of 1935 provides that no electric utility subject to the jurisdiction of the Commission shall, with respect to any transmission or sale, give undue advantage to any consumer or subject any consumer to an undue disadvantage or to maintain an unreasonable difference in rates, charges, service, or facilities either between locations or between classes of service (Federal Power Commission 1970).

This authority requires the Commission to test the provisions of a coordination agreement against the statutory provisions. Any discriminatory treatment among electrical utilities is unreasonable and too preferential unless the proponents can prove otherwise.

Under Section 202(b) of the Federal Power Act, the Commission is explicitly authorized to order the enlargement of transmission equipment (Federal Power Commission 1970). Upon complaint of a state commission or an electric utility, it can force a temporary connection of facilities and any generation, delivery, interchange, or transmission of electrical energy that will meet the emergency where emergency is defined to include a sudden increase in the demand for electrical energy or a shortage of electrical energy, of facilities for the generation or transmission of electrical energy, or of fuel or water for generating plants. Yet the Commission has not used this authority as a weapon to promote coordination. In view of the emergency created by environmental siting constraints, financing limitations, and the potential disappearance of smaller electric utilities, an analysis of the potential offered by Section 202 is needed.

The Commission has on occasion in the past required an electric utility to "wheel" electrical energy where "wheeling" involves the use of a third party's transmission lines to deliver electrical energy from a producer to a consumer. Consistent requirements of compulsory wheeling as seen above could increase efficiency. The consumer would be able to consider several generating sources to determine the arrangement of generation and transmission that will minimize his total electrical energy expenditures.

The Commission can exercise licensing and use leverage to encourage regional coordination and planning. For example, when a hydroelectric plant license issued by the Commission expires and the Commission is considering whether to issue a new license to the utility originally holding the license, it is reasonable to consider its behavior with regard to other utilities. One question that should be asked is whether the utility inhibited coordination.

Summarily, there exists a great deal of authority by which the Federal Power Commission could promote coordinated operation and planning in the electrical energy industry. That it should has been adequately demonstrated here.

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Modeling and Simulation of the U.S. Economy with Alternative Energy Availabilities

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The acute energy shortages of 1973–74 accentuated the pervasiveness of energy utilization in the U.S. economy and underscored the complexity of the system interrelationships. It was also revealed that little is known about these interrelationships. This article reports on a systems analysis of the short-run economic effects of alternative situations involving reduced energy availability. The impacts of several different energy availabilities are analyzed. Specifically, the situations considered are a 2% quantity reduction in domestic coal supply, a 1.0 and a 1.5 million barrel per day reduction in crude petroleum imports, and a 10% quantity reduction in natural gas supply.

Key words: energy policy, energy shortage, input-output analysis, linear programming.

The acute energy shortages of 1973–74 accentuated the pervasiveness of energy utilization in the U.S. economy and underscored the complexity of the system interrelationships. They also revealed that little is known about these interrelationships. This article reports on a systems analysis of the short-run economic effects of alternative situations involving reduced energy availability.

Input-output (I-O) analysis has long been used for studies of the direct and indirect effects of certain system changes. However, I-O analysis generally assumes that primary resources are available to support any level of production. In a short-run energy shortage situation, primary inputs such as crude petroleum are fixed in their availability. To investigate these short-run impacts this study incorporates I-O data into a linear programming model with primary input constraints directly imposed.

The impacts of several different energy availabilities are analyzed. Specifically, the situations considered are a 2% quantity reduction in domestic coal supply, a 1.0 and a 1.5 million barrel per day (MBD) reduction in crude petroleum imports, and a 10% quantity reduction in natural gas supply.

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Model Formulation

The objective is to

$$(1) \qquad \max LX,$$

which is the sum of gross dollar output within the modeled economy. Here, X is the n-element column vector of dollars of gross output by production sector and L is an n-element row vector of ones.

The constraints are specified in equations (2) through (11). The first constraint,

$$(2) \qquad (I - A)X - C_pH - IY = 0,$$

ensures that gross output (IX) equals demand, which consists of intermediate demand (AX) plus household personal consumption expenditures (C_pH) plus final demand (IY).[1] Household personal consumption expenditures are a linear function of household gross output (H) and are distributed among production sectors according to C_p. The second constraint,

$$(3) \qquad -WX + (1 - C_{ph})H - Y_h = 0,$$

[1] Final demand consists of gross private capital formation, exports, and government purchases.

is similar to equation (2) and requires that household gross output (H) equals employee compensation from the production sectors (WX) plus employee compensation for workers employed directly by households ($C_{ph}H$) plus final demand (Y_h). In order to limit deliveries to final demand,

(4) $$IY \leq D_f$$

represents n upper bounds (D_f) on maximum final demand accepted (Y) by the production sectors and

(5) $$Y_h \leq D_{fh}$$

is analogous to equation (4), giving a limit on maximum final demand accepted by households (D_{fh}). Equation (6),

(6) $$LY + Y_h - Y_{tot} = 0,$$

sums final demand accepted by the production sectors (LY) and households (Y_h) into a variable representing total final demand (Y_{tot}). Equation (7),

(7) $$E_1X + E_2H + E_3Y_{tot} - E_pP_d \leq Imp,$$

gives the quantity limitations of the five types of energy. Energy use by production sectors (E_1X) plus energy use by households (E_2H) plus energy used in meeting final demand (E_3Y_{tot}) is less than or equal to energy imports (Imp) plus domestic energy production (E_pP_d).[2] Domestic energy production is a linear function of gross output by the energy-producing sectors. Equation (8),

(8) $$-JX + IP_d = 0,$$

equates total gross output of energy-producing sectors (the element J_{ij} is 1 if sector i produces energy type j and is 0 otherwise) to the levels of the five energy production variables (P_d). To provide a physical upper limit (B_d) on domestic production of the five energy types,

(9) $$E_pP_d \leq B_d.$$

Equation (10),

(10) $$M_{tt}Y + M_{tth}Y_h = 0,$$

requires that trade and transportation final demand be proportional to the final demand for other sectors. The jth column of M_{tt} equals the trade and transportation margins required in selling and shipping final demand of production sector j. For the trade and transportation sectors these coefficients are -1. The nonnegativity specification on all variables is given by

(11) $$X, H, Y, Y_h, Y_{tot}, P_d \geq 0.$$

In addition, nonbinding accounting relationships are specified to yield information on employment, total value added, indirect business taxes, and property-type income.

The primal model described in equations (1) through (11) yields results on production activity, household activity, final demand, energy use, domestic energy production, and energy imports. In addition, dual variables (shadow prices) are generated. All shadow prices are in terms of contribution to the primal objective function—gross output. The dual model is presented in the appendix.

Empirical Specification of the Model

The model as stated above is developed consistent with theory and computational experience (McCarl et al.; Penn et al.; Penn, Irwin, and McCarl). The specification incorporates the U.S. Department of Commerce eighty-five sector published I-O data from 1967,[3] University of Illinois Center for Advanced Computation energy data (Simpson and Smith, Herendeen), and transportation and trade margins data synthesized from the published I-O data (U.S. Dep. of Commerce). The following sections describe particular aspects of the model formulation.

Closing Model with Respect to Households

The household sector is included as an endogenous sector along with the production sectors, due to the interest in economic interdependence including the induced effects of households. The activity of the household sector, as a supplier of labor services and recipient of wages, depends on the gross production level of the economy. To make the sector endogenous to the model, the personal consumption expenditure column (H) and employee compensation row of the I-O table are

[2] E_3 is energy used over and above the use in the production and household sectors.

[3] The problem was originally formulated using the more detailed 367 sector table but the solution of this problem was not feasible on any immediately available solver. This problem had 391 rows and 742 columns of which 368 were bounded. The density was 18.4%, which, when combined with the size of the problem, was the reason for the failure of the solving codes. The eighty-five sector problem had 109 rows and 178 columns (86 bounded) and a density of 44.3%.

made part of the Leontief matrix. This requires that the row and column totals are equal. However, in the 1967 table personal consumption expenditure exceeds employment compensation by almost $20 billion of nonwage personal income (U.S. Dep. of Commerce). This amount is entered as maximum final demand (D_{fh}), allowing up to this additional amount to be spent on consumption items. This formulation introduces a particular form of consumption function having an intercept equal to nonwage personal income and a constant marginal propensity to consume.

Choice of Objective Function

The I-O matrix and accompanying constraints define the eligible solution points, with the objective function directing the choice of a solution point. In order for the model to be meaningful, the solution and thus the objective function must be consistent with the behavior of the economy. The I-O matrix has been used previously in an optimizing framework by numerous authors (e.g., Chenery and Clark, Makower), and typical objective functions have maximized final demand accepted or consumption. Minimization of resource use has also been used but presents difficulties when there are multiple scarce resources, such as the five types of energy in this study. The objective of maximizing gross output (excluding households) is adopted because (*a*) in the unconstrained case this objective yields results consistent with Leontief I-O analysis (both in terms of activity levels and multipliers) and (*b*) it is assumed that the behavior of the economy can reasonably be represented by the production sectors maximizing their output, subject to the I-O matrix, which states that they only produce as much as demanded.

It could be argued that the behavior of the economy in an energy shortage situation cannot be represented by a single objective function. Here, consideration of individual producer behavior makes gross output maximization appear as the most reasonable single objective. In order to gain information on the response of the economy to an energy shortage under different behavioral assumptions, some alternative objectives are also used. These correspond to various policy considerations noted by Simon (1975a, b) and the *Economic Report of the President* and consist of maximization of (*a*) indirect business taxes (IBT), (*b*) property-type income (PTI), (*c*) total value added (TVA), which equals gross national product (GNP), and (*d*) employment (EMPL).

Transportation and Trade Margins

The U.S. Department of Commerce table is presented in terms of producers' prices, equivalent to values FOB. Such prices exclude distribution costs and wholesale and retail trade margins (but include excise taxes collected and paid by producers), which make up the differences between producers' and purchasers' prices. The trade margin on each item of the "bill of goods" is separately specified as a requirement from the trade sector. Similarly, transportation cost is separately specified as a requirement from the transportation sector. Without explicit treatment of the transportation, wholesale, and retail trade sectors, primary resource constraints may cause large reductions of activity in these sectors with only minor reductions in the other producing sectors. This means the margins could be greatly reduced while physical production is not, i.e., that produced goods are transported at no cost or with no trade margin. Thus, the relationship between production and margins must be specified and preserved. As the production level changes, so must the margins in accordance.

The matrix structure ensures correct accounting for domestic production, but a problem arises with respect to final demand. Generally, final demand of one sector is considered independent with regard to final demand of other sectors. However, this is not true in the case of transportation and trade margins, and in order to model this correctly, two rows linking final demand levels and margins are included in the model. The dollar requirements of transportation and trade of each sector for delivery of $1 to final demand are entered in these rows across the final demand columns. Thus, in a constrained solution where final demands are reduced, the margins will be reduced in proportion.

The Energy System

The energy data are usage of energy by each producing sector (Simpson and Smith). Energy is disaggregated into five basic types: coal, crude petroleum, refined petroleum, electricity, and natural gas. In order to model

accurately the energy system, both imported and domestically produced energy must be treated. Domestic production is attributed to the coal-mining sector for coal, the crude petroleum sector for crude petroleum, the petroleum-refining sector for refined petroleum, and the electric, gas, water, and sanitary services (utilities) sector for both electricity and natural gas.

Accounting for energy use to meet final demand is handled similarly to transportation and trade margins discussed above. Energy utilization (per dollar of final demand) coefficients are entered in the energy resources rows, and the model formulation is expanded to account for the energy required by final demand.

Results

Numerous simulations of alternative energy situations have been obtained with this model formulation. Space constraints permit only an abstraction of results from four situations to illustrate the model's capabilities. Solutions shown in table 1 are for: (*a*) a 2% quantity reduction in domestic coal supply, (*b*) a 1.0 and (*c*) a 1.5 million barrel per day reduction in crude petroleum imports, and (*d*) a 10% reduction in domestic natural gas supplies. The first is suggestive of the situation resulting from the coal miners' strike in 1974. The second and third situations are similar to the administration's energy strategy enunciated in January 1974 (Simon 1975a). The fourth is reflective of the situation suggested as possible for the East Coast and other areas in the winter of 1975–76, although it did not occur. The fourth simulation uses the alternative objective functions (noted above) to illustrate the effect of various assumptions regarding a single national economic goal. The reductions in energy availability are implemented as reductions in import availability or domestic production capacity for the pertinent energy type in constraints (7) and (9).

Coal

In 1967, before the acute energy shortages, the U.S. economy consumed 14.7 quadrillion

Table 1. Simulations of the Impact of Energy Reductions

	Base Gross Output (Mil. $)[a]	Reduction in: Coal 2% GO	Crude 1 MBD GO	Petroleum 1.5 MBD GO	Natural Gas of 10%, Alternative Objectives: GO	IBT	PTI	TVA	EMPL[c]
		% of Base							
Sector category									
Agriculture, forestry, fisheries	63,793	99.8[b]	97.2	94.3	94.6	94.6	94.3	94.6	94.8
Mining	24,959	98.3	93.3	90.9	89.4	89.4	89.6	89.3	89.3
Construction	103,281	99.8	94.5	93.3	98.4	98.7	97.5	98.7	98.7
Manufacturing	617,366	98.9	95.9	93.7	90.1	89.9	89.9	90.0	89.4
Transportation and communication services	112,657	98.9	95.8	93.4	91.8	91.9	91.7	91.8	91.8
Wholesale and retail trade	163,365	99.3	96.3	93.4	93.2	93.4	93.0	93.4	93.4
Finance, ins., and real estate	161,005	99.4	96.6	93.6	93.5	93.7	93.3	93.7	93.8
Services	150,156	99.4	96.4	93.6	93.5	94.0	93.6	93.7	94.0
Other	123,934	102.3	101.8	101.0	100.6	94.0	99.1	99.1	94.0
Aggregate economic indicators									
Personal consumption expenditures	490,660	99.4	96.7	93.3	93.8	93.9	93.4	94.0	94.0
Indirect business taxes	70,239	99.3	96.2	93.4	93.1	93.3	92.9	93.2	92.6
Property type income	257,745	99.1	96.2	93.7	92.7	91.1	92.9	92.8	91.0
Total value added (GNP)	799,074	99.3	96.4	94.2	93.2	92.8	93.0	93.3	92.8
Gross output	1,520,518	99.3	96.3	94.0	92.7	92.3	92.4	92.6	92.1
Employment (in thousands)	56,360	99.3	96.0	93.6	92.5	92.7	92.3	92.6	92.8
Final demand	304,728	99.7	96.6	95.5	92.9	91.5	93.0	92.9	92.4

Note: Categories included are defined by the U.S. Dep. of Commerce.

[a] 1967 I-O data without energy constraints.

[b] This figure indicates that agriculture, forestry, and fisheries produced 99.8% of the base production ($63,793 million) or $62,517 million worth of output.

[c] These indicate the objective function being maximized: GO = gross output, IBT = indirect business taxes, PTI = property-type income, TVA = total value added, and EMPL = employment.

British thermal units (BTU) of coal, practically all from domestic production. To simulate the impacts of the 1974 strike induced shortage, sometimes estimated at 2% of 1974 quantity, the domestic coal BTU availability (right-hand side on equation (9)) is reduced by that amount and the solution is obtained by maximizing gross output (*GO*). The results in table 1 indicate the short-run impacts of the relatively modest reduction to be small for most of the aggregated sector categories.[4] Individual sector impacts vary depending upon the coal-utilization intensity of the sector and its reliance on coal-intensive sectors for inputs. For the aggregate categories, levels are generally reduced by less than 1% with the exception of the mining sectors. The aggregate indicators reveal economic activity to be slowed only slightly, with GNP, personal consumption expenditure, employment, government tax revenues, and investment income reduced by 1% or less.

Crude Petroleum

Simulations of crude petroleum import reductions of 1.0 and 1.5 million barrels per day are obtained using maximization of gross output as the objective. These reductions are 65% and 100%, respectively, of the 1967 level of imports.[5] The impact on output levels of the aggregated real sector categories from the 1.0 million barrel per day reduction ranges from declines of 7% for mining to less than 3% for agriculture and related sectors. The "other" category, which includes dummy industries and imports, shows a slight increase as these sectors use little energy, and the negative trade balance of the base year solution is reduced due to the reduced level of energy importation. Aggregate economic activity is reduced by approximately 4% overall as shown by the indicators. Notably, unemployment increases 4% over the base year (1967) level, GNP declines 3.6%, and personal consumption expenditure and aggregate final demand are reduced slightly over 3%. The impacts of the 1.5 million barrel per day reduction are even more restrictive of economic activity but follow the pattern of the 1.0 million barrel per day reduction.

Natural Gas

A reduction in domestic natural gas supplies of 10% is simulated maximizing gross output and four alternative functions. First, considering the solution reflecting a maximization of gross output, the effects of a gas shortage are pronounced with real activity levels showing reductions of from almost 2% to 11%. The categories showing the largest decline are mining and manufacturing, especially the textile-related sectors. The aggregate activity level declines by 6% to 7%. Employment is reduced by 7.5%, and GNP declines by almost that amount with the other indicators being similarly affected.

An examination of this situation with the alternative objective functions show the difference in results to be slight. This is as might be expected since indirect business taxes and property-type income are components of total value added (the other component is employee compensation). Also, the similarity of these results to maximization of gross output is consistent since, generally, the correlation of total value added with gross output is high for most sectors.

The largest contrast in effects of objective function choice appears when results from these four criteria are compared to the results from maximizing employment. The relatively labor-intensive sectors are emphasized at the expense of those less labor intensive and a somewhat different pattern of production allocation emerges.

Natural Gas Shortage and Food and Fiber System

To further illustrate the type of information obtainable from the model, the impacts of the natural gas shortage (domestic capacity to produce is reduced by 10%) are examined for a representation of a food and fiber system.[6] This food and fiber system representation, composed of nineteen sectors from the eighty-five sector table, is shown in table 2. Gross income and employment totals shown exclude transportation and trade because food and fiber proportions of these sectors are small at this level of aggregation. The impacts on the component sectors of the system are generally consistent with the aggregate results presented

[4] While detail for individual sectors is available from the model, the sectors are grouped as in table 1 for space economy.

[5] BTU reductions are calculated using a conversion factor of 5.8 million BTU per 42 gallon barrel (Reardon, appendix, p. B-1).

[6] Actually, it is a shortage of both natural gas and electricity, since they are represented by the same utilities sector.

Table 2. Simulation of 10% Natural Gas Reduction in a U.S. Food and Fiber System

Sector	Gross Output		Final Demand	
	Base	Natural Gas Reduction 10%	Base	Natural Gas Reduction 10%
	(Mil. $)	(% of Base)	(Mil. $)	(% of Base Accepted)
Inputs				
Chemical and fertilizer mining	1,027	83.9	187	100.0
Chemicals and selected products	23,182	77.2	3,880	33.2
Petroleum refining and related industries	26,975	93.1	2,676	100.0
Farm machinery	4,826	99.1	3,829	100.0
Electricity, gas, water, and sanitary services	37,321	90.3	2,017	62.3
Production				
Livestock and livestock products	30,638	94.0	207	100.0
Other agricultural products	28,540	94.5	2,093	100.0
Forestry and forestry products	1,945	104.3	−200	0
Agricultural, forestry, and fishery services	2,670	94.8	49	100.0
Processing and distribution				
Food and kindred product processing	89,451	93.9	3,937	100.0
Tobacco manufacturing	7,940	94.6	789	100.0
Broad and narrow yarn fabrics, yarn and thread mills	15,966	90.0	465	0
Miscellaneous textile goods and floor covering	4,668	93.3	305	100.0
Apparel	22,566	93.9	621	100.0
Miscellaneous fabricated textile products	4,283	94.6	476	100.0
Lumber and wood products	12,905	96.5	529	100.0
Wooden containers	542	93.9	30	100.0
Transportation and warehousing	52,825	91.9	9,257	88.9
Wholesale and retail trade	163,365	93.2	11,448	88.9
Total final demand			22,890	84.2
Gross output[a]	315,445	92.3		
Employment (in thousands)[a]	10,630	93.1		

Note: Solution maximizing gross output. Categories as defined by U.S. Dep. of Commerce.
[a] The transportation and trade sectors are excluded.

in table 1, but the impacts may be seen more clearly with this level of detail.

For the natural gas shortage simulation, impacts vary considerably by sector. The five designated inputs sectors reduce output over a rather wide range. The chemicals and fertilizer sectors are affected most, being large direct users of natural gas. The farm-machinery-manufacturing sector is affected little by the reduction. Sales from the utilities sector, which contains gas utilities through which the 10% natural gas reduction is implemented, are reduced by approximately 10%.[7]

Three of the four agricultural-production-related sectors show output reductions. One sector, forestry and fishery products, shows an increase of 4%. The explanation for this apparently perverse result is the use of the gross-output-maximizing function, which favors sector production over use of the capital inflow.

Output impacts on the ten sectors designated as processing and distribution sectors are also varied. Eight sectors including the relatively large food and kindred product processing sector are reduced by from about 3% to 10%. The textile-related sectors are severely affected. For the fabric, yarn, and thread mills sector, the output reduction is 10% and for the other three textile-related sectors, it is 6% to 7%.

The transportation and warehousing sector is reduced by about 8% and trade about 7%. Gross income (sales) to the system is reduced

[7] This result is tempered by the fact that the utilities sector consists of both gas and electric utilities.

by almost 8% for this simulation. The system as defined has a base level employment of 10.6 million people, and the simulation of this fuel restriction indicates that a reduction of 7% would occur.

Final demands for the various sectors are also restricted differently under a fuel shortage. In any shortage, all equilibrium final demands cannot be accepted. The pattern of final demands accepted (shown in table 2) is seen to vary considerably across the sectors. It should be recalled that "final demand" in this model includes gross private capital formation, exports, and government purchases. Domestic consumption (personal consumption expenditure) is not included in final demand as it is treated as endogenous to the model (i.e., an intermediate product).

For the situation examined, the food and fiber system would be proportionately more severely affected than the economy as a whole. Employment declines indicated would be greater and output declines would show even greater disparity. These simulations reinforce the well-known overall conclusion that, given emergence of specific shortages, alternate schemes to alleviate their impact may produce similar results for the economy in the aggregate, but the impacts on individual sectors may be markedly different. For the selected sectors shown, the results further emphasize the direction and relative magnitudes of trade-offs that should be considered by policy makers in selecting one or more economic goals for emphasis over others.

Results presented and discussed have focused on sector gross output and aggregate activity levels. It is obvious that additional types of useful information can be gleaned from simulations with the model. Examples of this are the levels of sector final demands and sectoral and energy shadow prices.

In table 3, the total quantity of energy available is shown in terms of BTU and disaggregated into energy available through domestic production and imports. The figures reflect two situations: actual 1967 (base) and a 1 million barrel per day reduction in crude petroleum imports. Thus, table 3 corresponds to the simulation of the reduction in crude petroleum of 1 million barrels per day in table 1.

The simulation shows that the full domestic production capacity is used for crude petroleum and natural gas and for refined petroleum when crude petroleum imports are reduced. In addition, the crude petroleum imports are obviously at their limit. The creation of energy of other types is less than in the base situation. This reflects the general slow-down of the economy due to the petroleum shortage.

Interesting additional information generated by this simulation is the shadow price for available crude petroleum of $30 per million BTU.[8] Using the conversion factor 5.8 million BTU per barrel (Reardon, appendix, p. B-1), this translates to a gross output value of crude petroleum of $174 per barrel. This imputed value is much larger than the price paid for imported crude petroleum, which is in the

[8] For comparison, the shadow prices per million BTU of coal and natural gas from the 2% coal reduction and 10% natural gas reduction simulations are $50 and $70, respectively.

Table 3. Energy Balances for Base and for 1 Million Barrel per Day Reduction in Crude Petroleum Imports

		Domestic Production		Imports		Total	
Energy Type		Base	1 MBD	Base	1 MBD	Base	1 MBD
Coal	Base	14,715		6		14,721	
	1 MBD		13,961		6		13,967
Crude petroleum	Base	39,348		3,255		42,603	
and natural gas	1 MBD		39,348		1,138		40,486
Refined petroleum	Base	25,338		3,375		28,713	
	1 MBD		25,338		1,869		27,207
Electricity	Base	4,059		0		4,059	
	1 MBD		3,867		0		3,867
Natural gas	Base	18,018		456		18,474	
	1 MBD		17,626		0		17,626
Total	Base	101,478		7,092		108,570	
	1 MBD		100,140		3,013		103,153

Note: Figures are reported in 10^{12} BTU.

range of $10 to $15 per barrel. A decrease in the available quantity of crude petroleum imputes a very high value to petroleum and this in turn is likely to lead to extensive efforts to create substitutes. Certainly such a high imputed value should encourage exploration and/or technical substitution.

Conclusions

This paper has described and illustrated the use of a constrained I-O model for examination of primary resource constraints. A good example of the use to which this analysis can be put is given by the simulation of a natural gas shortage. The textile-related sectors of the economy (contained in the aggregate manufacturing category in table 1) are large users of natural gas. These sectors were severely affected by the simulated gas shortage. In other words, the model shows that, given the objective to maximize gross output, the rational action to take is to reduce activity in the textile industry. This conclusion may be compared with the actual policy followed by many natural gas suppliers in times of gas shortage. The accepted policy is to supply textile industries with gas on a "first interruptable" basis, which in effect means that activity in the textile industry is reduced. Thus, the appropriateness of that policy or other policies may be evaluated to some extent by this type of simulation.

Results available from the model must be viewed in the light of a combination of the separate assumptions employed both in linear programming and construction of the I-O table. Some of the more important assumptions present in the formulation described above are: (*a*) each commodity is produced by a single sector (industry); (*b*) the I-O formulation in general does not allow substitution; the formulation presented here permits "substitution" in the sense of underproducing for final demand, but the major component of final demand (personal consumption expenditure) is internalized in this formulation; (*c*) the inputs used by a sector are strictly proportional to output; (*d*) external economies and diseconomies are absent (additivity); (*e*) all relations are nonstochastic and continuous; (*f*) technology is fixed and dated—1967 I-O data are used;[9] and (*g*) electricity and natural gas are produced by the same sector.

An implication is that the economy is assumed not to have alternative production techniques, which might be less energy intensive. At best, this assumption is valid only in the short run. Also, the realism of the model relative to current conditions is lessened because of the changes in relative input (especially petroleum) and product prices since 1967. It is possible that problems related to the lack of substitution in I-O models could be dealt with more effectively if some of the information available to the U.S. Department of Commerce is not only aggregated into the I-O tables but also reported according to other technological classification.[10]

The approach of this study is to emphasize the short-run aspects of the problem. In the long run, it is likely that consumer demand adjustment and development of energy supplies will take place. These phenomena are not handled in this modeling effort. Likewise, no consideration has been made of balance of payments problems and price adjustments.[11] The longer run aspects of modeling energy constraints have been discussed by a number of authors in the proceedings of the 1975 Summer Computer Simulation Conference (American Institute of Chemical Engineers et al.).

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[9] Nelson has conducted some investigations using the 1967 I-O model and suggests that the 1967 data are applicable to at least 1974. The U.S. Department of Commerce now prepares an I-O table following each quinquennial Census of Business. The most recently available table for 1967 was released on computer tape in late summer 1974.

[10] In order to prevent duplication in information gathering, in this case by the Center for Advanced Computation, it may be desirable that data on resource usage are reported along with the I-O tables. A step in this direction has been reported by Just, Borko, and Morris. The same argument obviously follows from difficulties encountered in this study when attempts were made to handle the relation between final demand and trade and transportation margins discussed above. This can be seen as a simple extension of Bonnen's arguments on data. The use of the data needs to be considered along with its creation. The authors suggest that a wider conceptual base should be considered for the U.S. Department of Commerce data.

[11] A possible extension of the model presented here is the adoption of a price-quantity response system. Harrington has shown how a model similar to the one above can be structured to portray price responsive primary resources and final demands. The above model could be formulated in such a manner incorporating price-responsive energy supply and final demand and solved by separable programming, for example.

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Appendix

Dual Formulation

The dual of the programming model given in equations (1) through (11) is to

(A.1) $\min D'_f\gamma + D_{fh}\delta + Imp'\zeta + B'_d\theta$

(A.2) subject to $(I - A)'\alpha - W'\beta + E'_1\zeta - J'\eta \geq L'$,

(A.3) $-C'_p\alpha + (1 - C_{ph})\beta + E'_2\zeta \geq 0$,

(A.4) $-I\alpha + I\gamma + L\epsilon + M'_{tt}\kappa \geq 0$,

(A.5) $-\beta + \delta + \epsilon + M'_{th}\kappa \geq 0$,

(A.6) $-\epsilon + E'_3\zeta \geq 0$,

(A.7) $-E'_p\zeta + I\eta + E'_p\theta \geq 0$,

(A.8) γ, δ, ζ, and $\theta \geq 0$,

and

(A.9) α, β, ϵ, η, and $\kappa \gtreqless 0$.

The variables are defined as follows.

α is a vector indicating the value to the economy's gross output of accepting one additional dollar of demand (intermediate or final) by each production sector. The value can be either negative or positive depending on whether energy cost exceeds the value of production. α corresponds to equation (2).

β is a scalar, analogous to α but for the household sector, β corresponds to equation (3).

γ is a vector indicating the value to the economy of accepting one additional dollar of final demand by each production sector. These values are somewhat analogous to the output multiplier used in I-O analysis. γ corresponds to equation (4).

δ is a scalar, analogous to γ but for the household sector. δ corresponds to equation (5).

ϵ is a scalar, indicating the value of one additional dollar of final demand not requiring energy. This can be interpreted as the energy cost of meeting final demand. ϵ corresponds to equation (6).

ζ is a vector indicating the value of one additional unit of available energy either imported or domestically produced by energy type. ζ corresponds to equation (7).

η is a vector indicating the value of one additional dollar's worth of output from the domestic energy producing sectors by energy type. η corresponds to equation (8).

θ is a vector indicating the value of one additional unit of domestic energy capacity by energy type. θ corresponds to equation (9).

κ is a vector of values of one additional dollar of trade or transportation margin forced into final demand. κ corresponds to equation (10).

The Productive Value of Human Time in U.S. Agriculture

Wallace E. Huffman

The quantity and marginal productivity of farm husband and wife labor services allocated to their own farm work are assessed. A behavioral model of the farm firm is developed and implemented empirically by fitting a production function to county average per farm data for 1964 for Iowa, North Carolina, and Oklahoma counties. A comparison of marginal products of husband's and wife's labor inputs with opportunity costs yields the implication that net rural-to-urban human migration and reallocation of working time between own-farm and off-farm work by the remaining farm population had succeeded in getting rid of excess labor services in U.S. agricultural production in 1964.

Key words: education, extension, farm husbands, farm labor, farm wives, human time, production function.

This paper focuses on assessing the quantity and productivity of farm husband and wife labor services allocated to their own farm work. The assessment is possible because the 1964 Census of Agriculture records for the first and only time the actual hours of work on "own farm" and educational attainment of farm operators and other household members (U.S. Dep. of Commerce 1967). A behavioral model of the farm firm is developed to provide a framework for assessing the actual value of human time and other inputs, including education and agricultural extension, in agricultural production. The model is implemented empirically by fitting a production function to county average per farm data for 1964 for Iowa, North Carolina, and Oklahoma counties.

A comparison of implied marginal products of the inputs for representative farms of the three states yields the implication that the rural-to-urban migration of farm people and the reallocation of working time of the remaining farm husbands and wives between own-farm and nonfarm work have succeeded in getting rid of the excess labor services in agricultural production. However, only the marginal product of education for Iowa farm husbands and wives compares favorably with its marginal value at nonfarm work. The results also show a huge marginal product in agricultural production of agricultural extension agent time (in excess of $1,000 annually per day).

This article is organized as follows. First, a behavioral model of the farm firm is developed. The next section describes the data, discusses the empirical specification of the model, and reports the results. The final two sections present the implied marginal products and conclusions, respectively.

The Conceptual Model

The farm firm is assumed to take farm firm and household-supplied inputs and (other) purchased inputs and transform them into useful output. For farm firm and household-supplied inputs, the resource allocation should be largely unaffected by the payment or nonpayment of a wage or rental rate on household-owned resources because of the opportunity cost associated with alternative uses. For farm-family labor, hours allocated to farm work have a cost of the foregone alternative uses at nonfarm work and/or household production.

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Agriculture is a multiproduct industry, and most firms in agriculture are multiproduct firms that produce at least two broad classes of final products—crop products and livestock products. The production of these final products requires many of the same inputs, but the technical relationship between inputs and outputs seems likely to differ. For example, when livestock products dominate output, the livestock input to output ratio is likely to be higher than when crop products dominate output. In an attempt to capture differences of input parameters due to major product mix differences, the technical relationship between outputs and inputs is specified as

$$(1)\quad Y = Y_l + Y_c = A \prod_{i=1}^{n} X_i^{\alpha_i+\beta_i\rho},\ Y > 0,$$
$$Y_l \geq 0,\ Y_c \geq 0,\ X_i > 0,\ 0 \leq \rho \leq 1,$$
$$A > 0,\ 0 \leq \alpha_i + \beta_i\rho < 1,$$

where Y_l is the value of final livestock output, Y_c is the value of final crop output, ρ is the share of final livestock products in total final output, and A, α_i, and β_i are unknown parameters.[1]

Some properties of the production function (1) are the following. (*a*) Additivity of final products Y_l and Y_c, weighted by market prices for an output index, has the desirable property (for this study) of equaling total value of output.[2] (*b*) The index of output is homogeneous of degree 1 in the two products, i.e., doubling each product doubles the output index. (*c*) The elasticity of product transformation between Y_l and Y_c is infinitely large in the region of an optimal product mix. Inside this region, the marginal rate of product transformation is constant and equals the ratio of output prices (in quantity units) or unity (in value units). Thus, a dollar of crop products is locally a perfect substitute for a dollar of livestock products in the aggregate output index.[3] (*d*) The input index permits the weight of a particular input in the aggregate input index to change as the composition of aggregate output changes. For example, if crop products dominate aggregate output, the weight given to the livestock input in the input index can be small, but if the livestock products dominate output, the weight given to the livestock input in the input index can be large. Stated another way, the partial elasticity of aggregate output with respect to an input (or assuming competition, factors of production are paid their marginal product and decreasing returns to scale, the factor minimum cost shares of output) is permitted to vary with the product mix. (*e*) The elasticity of scale and degree of homogeneity of the input index

$$h(\rho) = \sum_{i=1}^{n} (\alpha_i + \beta_i\rho)$$

varies with the product mix of output. (*f*) The marginal rate of substitution in production between pairs of inputs at given factor ratios varies with the product mix of output:

$$MRS_{ij} = \frac{\partial Y/\partial X_i}{\partial Y/\partial X_j} = \frac{(\alpha_i + \beta_i\rho)}{(\alpha_j + \beta_j\rho)} (X_j/X_i).$$

Thus, holding relative factor prices and aggregate output constant, the optimal factor ratios for cost minimization vary with the output mix. (*g*) The elasticity of substitution between any two pairs of inputs is unity.

As an objective, the farm firm is assumed to maximize expected profit subject to anticipated production. This objective is appealing for agriculture. First, the actual prices are unknown at the time that production decisions are made so the assumption is that farmers base scale decisions on the expected prices of outputs. This implies that farmers are risk neutral. Second, because random weather conditions introduce disturbances into the input-output relationship, the quantities of actual outputs are unknown at the time that resource allocation and scale decisions are made. Consequently, farmers are assumed to make farm production decisions based upon anticipated output and not on actual output. Thus, the disturbance in the production equation affects only output and is not transmitted to the other variables of the system.

The Empirical Analysis

The data, empirical specification of the model, and the empirical results are presented and discussed in this section.

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[1] Separate production functions for the two final products are not implied. Production is joint. Furthermore, it is a useful simplifying assumption that the true coefficients in the production function depend on the share of livestock products in the total output (or on the type of farm).

[2] A transformation function of the Cobb-Douglas, CET, or translog type in the outputs does not have this property. Furthermore, a Cobb-Douglas form has the wrong curvature, convex to the origin (Mundlak).

[3] A straight-line segment of the transformation curve will imply specialization in production only if the infinite elasticity of product transformation holds for all combinations of Y_l and Y_c. But for all possible combinations of Y_c and Y_l, the transformation function is assumed to be (quasi) concave. For a discussion of properties of production possibility frontiers, see Christensen; Christensen, Jorgenson, and Lau.

The Data

The observations are average per farm aggregates for all 276 counties of Iowa, North Carolina, and Oklahoma. Observations from these three states were chosen because their agricultural sectors continue to be important industries, they provide a mixture of farming activities (with the predominant type of farm ranging from tobacco and cotton to dairy and livestock ranch), and they represent different geographic regions of the United States—Midwest, Southwest, and Southeast. (See table 1 for a summary description of the data and variables used in the analysis.)

The data base provided by combining data from the 1964 Census of Agriculture (U.S. Dep. of Commerce 1967) and from U.S. Department of Agriculture publications of the same period (Ibach and Adams; Sellers 1969, 1970; Strickler) is a rich source of raw data for deriving the empirical measures of the variables required in this study. In particular, it is a richer data base than the 1969 Census of Agriculture (U.S. Dep. of Commerce 1972). Farm outputs and inputs are measured as flows. Output by final product type is gross product and is measured as value of sales, home consumption, rental of farm dwellings, government farm program payments, and net increase in farm inventories.[4] The inputs of

[4] When the objective is to obtain unbiased estimates of the parameters of the average per farm production function, the

Table 1. Summary Statistics of Total Sample and Subsamples, 1964

	Arithmetic Means (Standard Deviation)			
Variables	Whole Sample (n = 276)	Iowa Counties (n_1 = 99)	N. Carolina Counties (n_2 = 100)	Oklahoma Counties (n_3 = 77)
Aggregate output ($/year)	11,987.0 (6,676.0)	17,772.2	8,466.6	8,884.7
Crop output	5,659.7 (3,659.1)	6,041.1	6,049.6	4,663.0
Livestock output	6,327.7 (5,170.8)	11,915.0	2,417.0	4,221.7
Land and buildings ($/year)	2,568.5 (2,565.3)	5,510.5	926.9	906.9
Fertilizer ($/year)	369.7 (248.4)	438.3	413.5	224.9
Machinery ($/year)	1,754.6 (779.9)	2,513.2	1,188.0	1,515.2
Livestock and seed ($/year)	3,811.1 (3,071.4)	6,744.2	1,566.7	2,955.1
Hired labor (days/year)	59.7 (53.6)	34.4	97.0	43.7
Farm husband (days/year)				
Days own-farm work	194.0 (68.2)	275.9	142.4	155.7
Days off-farm work	66.2	43.2	68.9	101.6
Total days worked	260.2	319.1	211.3	257.3
Farm wife (days/year)				
Days own-farm work	70.1 (28.3)	104.9	40.4	63.8
Days off-farm work	44.6	31.4	60.5	40.9
Total days worked	114.7	136.3	100.9	108.7
Education (years)				
Farm husband	9.2 (1.25)	10.2	7.8	9.7
Farm wife	10.0 (1.13)	10.9	8.8	10.3
Extension (one-tenth day/year)	1.85 (2.01)	0.64	3.18	1.69
ρ	0.506 (0.220)	0.66	0.33	0.53

Note: See the appendix for the derivation of labor and education variables and Huffman (1976, pp. C1–C10) for derivation of other variables.

three different labor services are derived from flow data on actual (not available) number of man-days worked per year on farms. Man- (woman-) days of farm work per year are derived from adjusted weekly hours of farm work during the census week by farm operators (nonoperator household members) and from annual expenditures on hired labor. Measuring the labor input, especially farm family, as the quantity of actual services used corrects conceptual and measurement errors that exist in other studies of agricultural production. The conceptual error is that the stock of labor contributes to production rather than the flow of labor services (Doll). The measurement error is the use of the stock of workers as a proxy for labor services actually used in production. The cross-sectional rates of conversion of the stock of workers to labor services used in agricultural production differ because of systematic variation in (the variables that determine) both the total supply of working time of individuals and the relative allocation of total working time between farm and off-farm work.[5]

Education of farm husbands (wives) is an index derived as an income weighted average of the number of farm operators (wives of farm operators) in seven different schooling completion classes. Agricultural extension is derived from unpublished Federal Extension Service flow data for 1960 as the annual average number of one-tenth man-days allocated to crops and livestock activities by agricultural extension agents (doing primarily agricultural work) per farm (USDA 1961). The use of 1960 rather than 1964 data was necessitated by data availability. One can argue, however, that there is a time lag between the expenditure of extension agent time assisting farmers and the observed effect on agricultural production. The length of this lag is unknown, but a one- to four-year lag for the primary impact seems plausible (Evenson).

proper definition of output is gross output and intermediate inputs are to be included as inputs (Christensen, Domar, Star).

[5] Kislev used the number of workers as a proxy for man-years of available labor services. Heady and Timmer in their separate studies used available man-months and man-days, respectively, as the quantity of farm supplied and hired labor input. Griliches works from an assumption of a given number of available man-days or annual man-years per worker, but he adjusted this number downward to account for days of off-farm work (1963, 1964). Thus, even in better approaches, measurement errors arise in the hours-of-farm-work variable because of incorrect allocation of total available time among nonearnings activities (consumption) and time at farm and off-farm earnings activities. An exception is Fane's study, which uses available hours from the 1964 Census of Agriculture (1972, 1975).

The fertilizer input is measured as price-weighted primary plant nutrients, and land-and-building services are measured as the rental on the value of farm land and buildings valued at 1954 prices, adjusted to the 1964 mix of land-and-building characteristics and to remove the implied value per acre of being close to standard metropolitan statistical areas. Machinery services are measured as the rental on an inventory of a selected group of machines on farms in 1964 plus expenditures on petroleum products. The livestock and seed inputs are lumped together and measured as the rental on the inventory of breeding stock plus expenditures on purchased livestock, feed, and seed.[6]

The Empirical Specification

The productivity analysis is to be pursued through direct estimation of the natural logarithmic transformation of the production function. The empirical specification of the production function contains three separate labor inputs: hired, farm husband, and farm wife. Furthermore, the elasticity of substitution between all pairs of inputs in equation (1) is restricted to unity. This assumption may not be too objectionable for pairs of inputs not containing two labor inputs, but one can reasonably ask whether there is empirical evidence to support a unitary elasticity of substitution between pairs of labor inputs.

Direct empirical evidence shows that the restriction to unitary elasticity of substitution between pairs of labor inputs is not too severe. By assuming a more general constant elasticity of substitution (CES) technical relationship between inputs and aggregate output and profit maximization (or cost minimization), the elasticity of substitution between pairs of labor inputs can be estimated from wage and input-quantity data. Taking the wage rates as exogenous, the relationship between relative factor quantities and relative factor prices is

$$(2)\quad \ln(X_i/X_j) = \ln(\gamma_i/\gamma_j) - \sigma_{ij}\ln(W_i/W_j),\ i \neq j,$$

where γ_i and γ_j are distribution parameters, $\sigma_{ij} = d(\ln(X_i/X_j))/d(\ln(W_i/W_j))$ is the elasticity

[6] Given that production function parameters vary by product mix of output and that seed input contributes primarily to crop output and livestock input primarily to livestock output, one might question the inclusion of the seed input with the livestock input. Combining the seed input with the fertilizer input, however, contaminates a relatively good fertilizer variable. There is not much "information" in the seed-expenditure data.

of substitution between inputs X_i and X_j, and W_i and W_j are wage rates for X_i and X_j.

USDA data are available on state average daily wage rates paid hired farm labor (USDA 1965), and by making an assumption that the wage rate for off-farm work by farm husbands and wives is the opportunity cost of their time at own-farm work, county average daily wage rate data are available for farm husbands and wives (U.S. Dep. of Commerce 1967). Farm husband (wife) farm labor is measured in efficiency units as man- (woman-) days times the education index (Griliches 1970). To permit the labor input ratios to vary by product mix, the equation to be fitted is

$$(3)\ \ln (X_i/X_j) = a + b_{ij} \ln (W_i/W_j) + c\rho + \epsilon,$$

where $\sigma_{ij} = -b_{ij}$, and ϵ is a random disturbance.

The results from fitting equation (3) by classical least squares estimation method to the 276 observations on county aggregate data are reported in table 2. Two striking implications from these results are that the elasticity of substitution between pairs of farm labor inputs, hired farm wife, hired farm husband, and farm wife–farm husband, is "low" and that the labor input ratios vary by product mix, holding relative wage rates constant. The results imply that the highest degree of substitutability is between hired and farm wife labor services ($\sigma_{ij} = 1.2$) and that the lowest degree of substitutability is between farm wife and farm husband ($\sigma_{ij} = 0.12$) labor services. An intermediate degree of substitutability exists between hired and farm husband labor services ($\sigma_{ij} = 0.68$). Thus, hired and farm wife labor services are a poor substitute for farm husband labor services. One explanation is that the labor services of farm husbands are a different type of input than farm wife labor and hired labor services because of the relatively large share of farm husband's time that is allocated to allocative decision making (Huffman 1974). Farm wife labor and hired labor services are allocated primarily to physical work.[7]

The results also imply that there is a very definite impact of product mix on labor input ratios, holding relative wages constant. Livestock production, as opposed to crop production, is intensive in farm husband and wife labor services relative to hired labor services and is intensive in farm wife labor services relative to farm husband labor services. Furthermore, the failure to take into account product mix differences in estimating the elasticity of substitution between pairs of labor inputs (when product mix differences matter) biases upward the size of the estimated elasticity of substitution.

The conclusion, based on the results in table 2, is that the assumption of unitary elasticity of substitution between pairs of labor inputs in this study can be accepted at a small cost relative to a more general input specification that is much more difficult to estimate, e.g., a nested CES function or CES nested in a

[7] However, if there are random errors of measurement in both the labor input and wage rate ratios that are uncorrelated, the estimate of the elasticity of substitution will be biased toward zero (Johnston).

Table 2. Estimates of the Elasticity of Substitution between Pairs of Farm Labor Inputs, 1964

	a	b_{ij}	c	R^2	σ_{ij}
Hired/farm wife	−7.342	−1.152	−2.853	0.583	1.152
	(−43.53)[a]	(−5.06)	(−13.79)		(5.06)
	−9.332	−2.581		0.259	2.581
	(−82.02)	(−9.787)			(9.787)
Hired/farm husband	−9.057	−0.682	−2.652	0.512	0.682
	(−59.45)	(−4.20)	(−14.62)		(4.20)
	10.768	−1.326		0.129	1.326
	(−82.79)	(−6.37)			(6.37)
Farm wife/farm husband	−1.915	−0.115	0.458	0.153	0.115
	(−48.75)	(−1.96)	(6.54)		(1.96)
	−1.690	−0.151		0.021	0.151
	(−82.70)	(−2.40)			(2.40)

Note: These least squares estimates of the parameters in equation (3) are averages for 276 counties of Iowa, North Carolina, and Oklahoma. See the appendix and Huffman (1976, pp. C1–C10) for sources and derivation of variables.
[a] t-ratios are in parentheses.

Cobb-Douglas function. Furthermore, the specification of the production function (1) permits pairs of labor input ratios to vary by product mix (as implied in table 1), holding the marginal rate of substitution in production constant.

The parameters of the production function are to be estimated directly from aggregate average data. The specification is

$$(4)\quad \ln Y = \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln X_i + \sum_{i=1}^{n} \rho\beta_i \ln X_i + \delta\rho + \mu,$$

where α_i, β_i, and δ are unknown and estimable parameters. The specification of the disturbance term in the production function ($\ln e^{\delta\rho+\mu} = \delta\rho + \mu$) is an attempt to take account of heteroscedasticity of the disturbances that may be due to differences in the product mix of output. A discussion can be found elsewhere of potential problems with statistical identification of the production function (Griliches and Ringstad) and simultaneous equation bias (Hoch; Zellner, Kmenta, and Dréze) when the production function is estimated directly by the method of classical least squares.

Furthermore, estimates of parameters of equation (4) from aggregate average data may compare favorably with estimates from microdata. Given the comparative advantage of economic models for explaining the behavior of averages rather than individual decision units, the aggregation bias from fitting an empirical model to aggregate average data may be less serious than the specification errors from fitting it to individual farm data (Grunfeld and Griliches), where at best the model captures the effect of the most important variables on individual output. Furthermore, even if individual farm data from the census were available, it is plausible that measurement errors in output, the dependent variable, are smaller, perhaps zero, for aggregate average data than for individual farm data. In this case, estimates of the parameters of the production function from aggregate average data may be better estimates than estimates from microdata (Aigner and Goldfeld).[8]

The Empirical Results

The results from fitting equation (4) to 276 county average per farm aggregates are reported in table 3. The performance of the variables is remarkable.[9] All the estimated α_i's are positive and significantly different from 0, except for the coefficient of fertilizer.

Coefficients of all variable inputs except for fertilizer and machinery inputs differ significantly by product mix of output. All variations seem plausible. As the share of final livestock products in total final output (i.e., ρ) increases, the size of $\alpha_i + \rho\beta_i$ declines for land-and-building services and the labor inputs and increases for the livestock and seed input. Furthermore, the five nonzero β_i's imply that all cost-minimizing factor ratios except one vary by product mix of output, holding relative factor prices constant (see table 4). One might be surprised that the ratio of land to all the other variable inputs declines as the share of livestock products in total output increases, but land-and-building services are measured as a rental value on constant-quality land and buildings for current agricultural production. Clearly a land-and-buildings input measured as acres would increase as ρ increases, but acres evidently do not rise as fast as the price per acre falls when ρ increases. As ρ increases, the other factor ratios move as expected. The ratio of the livestock and seed input to all other inputs increases, the ratio of hired to farm husband and farm wife labor services declines, and the ratio of farm husband to farm wife labor services increases. The latter is a contradiction of a result reported in table 2. There, the ratio of farm wife to farm husband labor services increases as the share of livestock products in total output increased.

The coefficients of the variable inputs in

[8] The outputs and inputs are measured as arithmetic averages of aggregate data, but correct aggregation of outputs and inputs requires geometric averaging of microdata. The seriousness of the aggregation error is unknown, but it is unlikely to be very large in a relatively narrowly defined industry such as agriculture (Walters). When a variable is log, normally distributed, use of the arithmetic mean rather than geometric mean results in the size of the variable being generally biased because a factor of proportionality that depends on its variance is ignored. Aggregation bias is discussed in Theil and Green.

[9] Unrestricted estimates of the coefficients of equation (4) were first obtained, but high intercorrelation between the variables led to generally small t-values for estimates of some β_i's and δ. Experiments were performed on equation (4) by constraining different plausible sets of β_i's to being equal, being zero, and/or δ to being zero. The reported regression performed the best in the sense of having small residual variance and having estimated coefficients significantly different from zero. A test of the null hypothesis that the linear restrictions on the coefficients of the production function are fulfilled (i.e., $\beta_2 = \beta_3 = \beta_9 = \delta = 0, \beta_6 = \beta_7$) against the unconstrained version of the production function led to a calculated F-value of 1.571. Since the critical F-value at the 5% level with 4 and 256 degrees of freedom is 2.41, the null hypothesis cannot be rejected at the 5% significance level.

Table 3. Estimate of the Joint Product Aggregate Agricultural Production Function, 1964

Input[a]	Regression Coefficient (t-ratios)	Implied Coefficients (t-ratios)		
		$\rho_{min} = 0.051$	$\rho_{mean} = 0.506$	$\rho_{max} = 0.904$
Land and buildings	0.081	0.075	0.026	−0.017
	(2.345)	(2.14)	(1.44)	(−0.59)
Fertilizer	0.026	0.026	0.026	0.026
	(1.324)	(1.32)	(1.32)	(1.32)
Machinery	0.383	0.383	0.383	0.383
	(8.565)	(8.57)	(8.57)	(8.57)
Livestock and seed	0.129	0.163	0.463	0.727
	(4.580)	(6.04)	(19.29)	(21.44)
Hired labor	0.195	0.184	0.083	−0.005
	(7.542)	(7.36)	(4.15)	(−0.15)
Husband man-days × husband education	0.495	0.486	0.405	0.335
	(9.228)	(9.00)	(7.36)	(5.78)
Wife woman-days × wife education	0.205	0.196	0.115	0.045
	(3.003)	(2.88)	(1.69)	(0.65)
Extension	0.015	0.015	0.015	0.015
	(3.606)	(3.61)	(3.61)	(3.61)
ρ × land and buildings	−0.108			
	(−1.870)			
ρ × livestock and seed	0.661			
	(14.141)			
ρ × hired labor	−0.221			
	(−4.153)			
ρ × husband man-days × husband education	−0.177			
	(−10.943)			
ρ × wife woman-days × wife education	−0.177			
	(−10.943)			
D_2	0.193	0.193	0.193	0.193
	(2.247)			
D_3	0.025	0.025	0.025	0.025
	(0.462)			
Intercept	−5.108	−5.108	−5.108	−5.108
	(−3.951)			
$R^2 = 0.976$	$s^2 = 0.01071$	$h = 1.513$	1.503	1.494

[a] Variables are in natural logarithms, except for extension, ρ, and state dummy variables (D_2 and D_3), which are in level form. The regression was estimated subject to linear constraints: (*a*) β_i's being 0 for Fertilizer, Machinery, Extension, and δ being 0 for ρ and (*b*) β_i's being equal for farm husband and wife labor. The "intercept" of the regression equation estimates the constant term of the log linear production function for Iowa counties. The coefficients of D_2 and D_3 estimate the change in the constant term of the log linear production function for North Carolina and Oklahoma counties, respectively. For more details of variable definitions, see table 1 and appendix.

table 3 imply sizable economies of scale for the aggregate input index (agricultural production). The size of the scale parameter evaluated at the sample's arithmetic mean for ρ (0.506) is 1.503, at the minimum observed value of ρ (0.051) is 1.513, and at the maximum observed value of ρ (0.904) is 1.494. Thus, scale economies are slightly larger for a mix of output concentrated with final crop products than concentrated with final livestock products.

The size of the agricultural extension input is largely outside the direct control of farmers. The Cooperative Extension Service is part of a mammoth publicly supported information system that supplies at a zero direct cost to farmers the decoded results and implications from basic and applied research conducted at or through the state agricultural experiment stations and the USDA. In addition, the extension agents serve as consultants to farmers on technical production problems. Thus, time spent by extension agents assisting farmers should and does contribute significantly to explaining output.

No economic significance should be placed on the signs of the estimated dummy variables. Procedures used in deriving measures of the inputs that are common to all counties within a state but that differ across states can lead to differences in the intercept of the regression.

Table 4. Change in Relative Factor Intensities as Share of Livestock Products in Total Output Increase, 1964

	Change: Column Input/Row Input[a]					
Variable Inputs	Land and Buildings	Fertilizer	Machinery	Livestock and Seed	Hired Labor	Husband Labor
Fertilizer	−					
Machinery	−	0				
Livestock and seed	−	−	−			
Hired labor	−	+	+	+		
Husband labor	−	+	+	+	−	
Wife labor	−	+	+	+	−	+

[a] Assuming cost minimization $\frac{\partial Y/\partial X_i}{\partial Y/\partial X_j} = \frac{(\alpha_i + \beta_i \rho)}{(\alpha_j + \beta_j \rho)} (X_j/X_i) = W_i/W_j$, where W_i and W_j are prices of X_i and X_j, determine the sign of $\frac{\partial(X_i/X_j)}{\partial \rho} = \frac{(\beta_i \alpha_j - \alpha_i \beta_j)}{(\alpha_j + \beta_j \rho)^2} (W_j/W_i)$. Estimates of β's and α's are taken from table 3.

The Implied Marginal Products

Implied marginal products for representative farms of each of the three states are derived from the estimated production function and sample information (see table 5). A representative farm of a state is defined as a farm in which values of variables equal subsample mean values calculated over all counties of the state. Output and the inputs land and buildings, fertilizer, machinery, livestock and seed, and education are measured in units of dollars per year, so the units on the marginal products of these inputs are dollars of output per dollar of input per year or return per year. The labor and extension inputs are measured in units of days (one-tenth for extension) per year, so the units on the marginal products of these inputs are dollars of output per (one-tenth) day of input per year. Given that the scale parameter exceeds unity (about 1.5) and assuming that marginal products are proportional to marginal factor cost for the variable inputs, the marginal factor costs (products) should be inflated (deflated) by 1.5 before comparing with marginal products (factor costs) for the variable inputs.

The implied marginal products of both the land-and-buildings input and fertilizer input for representative farms indicate that the marginal products are (significantly, except for fertilizer for the Iowa farm) less than marginal factor costs, i.e., \$1 of input produces less than \$1 of output.[10] Two possible explanations for the unusually low marginal products for the land-and-buildings input are first, that government farm programs (prior to 1964) created economic incentives (payments) to permanently retire farmland from production and to divert farmland to alternative uses. These programs could cause measurement errors in the land-and-buildings input and a small estimated coefficient on the input. Second, an overestimate of the inflation factor on prices of farmland and buildings between 1954 and 1964 (or of the interest rate) for each state would overestimate the denominator used in calculating the marginal product of land and buildings (although it would not affect estimates of the coefficient) and thereby cause a smaller marginal product than otherwise. For the fertilizer input, the marginal products are less than marginal factor costs for all three representative farms, but the difference is statistically significant (at the 5% level) only in North Carolina.

For machinery services, the implied marginal products indicate that the marginal products are significantly larger than marginal factor costs for all three representative farms. This finding is not surprising. There has been a fall in the relative price of machinery services during the 1950s and 1960s and there have been large increases in their rate of usage

[10] The implied marginal products are derived as $(\hat{\alpha}_i + \hat{\beta}_i\bar{p})\hat{Y}/\bar{X}_i$ except for extension, which is derived as $\hat{\alpha}_i\hat{Y}$, where the $\bar{X}_i$'s are geometric means of the inputs, except for extension and $\bar{p}$, which are arithmetic means, and $\hat{Y} = \exp[\hat{\alpha}_0 + \sum_{i=1}^{n} (\hat{\alpha}_i + \hat{\beta}_i\bar{p})\ln \bar{X}_i]$. These are (biased) conditional median values of the marginal products (Goldberger). To test the hypothesis that marginal products equal marginal factor costs, a test statistic was calculated as the marginal product less marginal factor cost (multiplied by 1.5 for all the variable inputs) and all divided by the approximate standard errors of the marginal products, $(\hat{Y}/\bar{X}_i)[\mathrm{var}(\hat{\alpha}_i + \hat{\beta}_i\bar{p})]^{\frac{1}{2}}$. Properties of these standard errors are discussed by Carter and Hartley and by Fisk. The test statistic is distributed approximately as the t-statistic with 260 degrees of freedom.

Table 5. Implied Average Marginal Products for Representative Farms, 1964

	Geometric Means (Subsamples)			Marginal Products[a] (Standard Errors)		
Variable	Iowa	N. Carolina	Oklahoma	Iowa	N. Carolina	Oklahoma
Aggregate output predicted (1964$/year)	20,206.3	6,693.3	7,289.3	—	—	—
Land and buildings (1964$/year)	5,113.0	844.6	611.4	0.038	0.359	0.283
				(0.08)	(0.17)	(0.22)
Fertilizer (1964$/year)	409.5	318.0	175.1	1.283	0.547	1.082
				(0.99)	(0.42)	(0.83)
Machinery (1964$/year)	2,488.5	1,075.0	1,370.0	3.110	2.385	2.038
				(0.37)	(0.28)	(0.24)
Livestock and seed (1964$/year)	6,111.8	1,126.0	2,654.3	3.306	2.063	1.316
				(0.09)	(0.13)	(0.07)
Labor						
Hired (man-days/year)	32.0	70.6	38.0	31.03	11.57	14.94
				(15.5)	(1.8)	(4.0)
				[10.90][b]	[6.60]	[9.10]
Husband (man-days/year)	273.7	140.4	153.1	27.92	20.81	19.10
				(4.2)	(2.6)	(2.7)
				[16.71]	[13.67]	[15.96]
Wife (woman-days/year)	104.7	39.9	63.8	17.02	24.59	12.70
				(13.2)	(11.5)	(7.8)
				[13.84]	[11.48]	[12.84]
Education (1959$/year)						
Husband	5,594.8	5,104.0	5,648.6	1.366	0.573	0.518
				(0.20)	(0.071)	(0.071)
Wife	3,043.4	2,775.7	2,994.0	0.585	0.353	0.271
				(0.46)	(0.17)	(0.17)
	Arithmetic Mean					
Extension	0.64	3.18	1.69	303.09	100.40	109.34
				(80.8)	(26.8)	(29.2)
ρ	0.66	0.33	0.53	—	—	—
$h(\rho)$				1.499	1.507	1.502

[a] Regression coefficients were taken from table 3. See footnote 10 for definitions of marginal products.
[b] The numbers in brackets are cost per day in 1964 of respective type of labor. For hired labor the cost is the state average daily wage rate (USDA 1965). For husbands and wives, the cost is the geometric average daily wage rate for off-farm work by farm husbands and wives, respectively (see appendix).

(Hayami and Ruttan). However, the increase has been too small. For livestock and seed services, the marginal product is significantly larger than marginal factor cost for the Iowa and North Carolina farms, but it is significantly below marginal factor cost for the Oklahoma farm.

Turning to the farm-labor inputs, the marginal product of hired labor is larger than marginal factor cost for all three farms, and it is significantly different from marginal factor cost (at the 5% level) for the North Carolina farm (see table 5). Thus, these results imply that it would have been profitable in 1964 for North Carolina farmers to have used larger quantities of hired labor in agricultural production. For farm husband labor, the marginal product of own-farm work is larger than the marginal (opportunity) factor cost (the wage rate for off-farm work) for the Iowa and North Carolina farms, but it is less than marginal factor cost for the Oklahoma farm. The differences between marginal products and marginal factor costs, however, are not statistically significant at the 5% level for any of the farms. For farm wives, marginal (opportunity) factor cost of farm work is larger than the marginal product (but not significantly) for the Iowa and Oklahoma farms. For the North Carolina farm, the marginal product of farm wife labor is larger than marginal factor cost, but the difference is not significant here either. Thus, hired labor is the only farm-labor input in 1964 farm production that shows significant nonoptimal factor usage.

The education indexes give the income that the average education mix of farm husbands (wives) of a county would generate in the nonfarm labor market in 1959. Thus, the marginal products of education are measured as 1964 dollars of farm output per 1959 dollar of nonfarm wage input. If the increase in nonfarm

wages between 1959 and 1964 was equal to the difference between the farm and nonfarm cost of living, then the marginal products of education should be unity. For farm husbands, the marginal product of education is larger than marginal (opportunity) cost on the Iowa farm (significantly different at 8% level), but it is smaller than marginal factor cost (significant at 5% level) for the North Carolina and Oklahoma farms. For farm wives, the marginal product of education is below marginal (opportunity) cost for all three farms, but it is not significantly different from marginal cost for the Iowa farm, although differences are significant for the North Carolina and Oklahoma farms. Thus, these results imply that only on Iowa farms was it an economically wise decision in 1964 for households to have acquired additional education for husbands and wives and to have employed these skills on their own farm rather than at nonfarm work.[11]

The implied marginal product of agricultural extension is huge for all three representative farms, but it is largest for the Iowa farm. The marginal product is $303 annually (per farm) for each one-tenth day of extension time (per year) and is $100 and $109 annually per one-tenth day of extension time for the North Carolina and Oklahoma farms, respectively.[12] The size of the extension input is not under the direct control of farmers; it is determined at the aggregate level by the government sector. Thus, the relevant question is what is the social rate of return to allocation of resources to extension? Answering this question requires information on the marginal social value of added output and data on the marginal social opportunity cost of resources allocated to added units of extension. The latter data are not readily available. A conjecture, however, is that the estimated social return would roughly support Griliches's estimate of the social rate of return to agricultural research and extension (1964).

[11] Farm husband and wife labor were measured in efficiency units as the product of days of farm work per year times the education index. Thus, the estimated coefficients of education and days of farm work were constrained to being equal. Also, national average levels of income by education were used in deriving the education indexes. Locally, levels of income by education may be lower than the national average.

[12] The specification of the production function results in the marginal product of extension being a linear function of predicted output. Given the differences in the size of predicted output for the representative counties, differences in the marginal product of extension per farm could be overstated. Also, the quality of agricultural extension time may be affected by quality of research in the associated agricultural experiment station.

Conclusion

This paper focused on assessing the quantity and marginal productivity of farm husband and wife labor services allocated to their own farm work. A behavioral model of the farm firm provided a framework for assessing the actual value of human time and other inputs, including education and agricultural extension, in agricultural production. The model was implemented empirically by fitting a production function to county average per farm data for 1964 for Iowa, North Carolina, and Oklahoma counties. The estimated coefficients of the production function implied that all cost-minimizing factor ratios except one vary by product mix of output, holding relative factor prices constant.

The implied marginal products of inputs were compared with marginal factor costs for representative farms in each state. The finding of a marginal product of hired labor that was larger than marginal factor cost for representative farms for all three states (significant for North Carolina) implies underuse of the hired-labor input. Farmers could have increased their farm profits by using a larger quantity of hired labor. Although the marginal product of farm husband labor was larger than marginal (opportunity) cost for the Iowa and North Carolina farms and less than marginal factor cost for the Oklahoma farm, none of the differences was statistically significant. Similarly, the marginal product of farm wife labor was less than marginal (opportunity) cost (at nonfarm work) for Iowa and Oklahoma farms and was larger than marginal factor cost for the North Carolina farm, but again none of the differences was statistically significant. Thus, farm households seem to be allocating husband's and wife's working time between own-farm and off-farm work in a fashion that maximizes farm household income. Furthermore, these results suggest that the rural-to-urban migration of farm people and reallocation of working time of the remaining farm husbands and wives between own-farm and nonfarm work prior to 1964 have succeeded in getting rid of the excess labor services in agricultural production.

The finding for the Iowa farm that the marginal product of farm husband's education was larger than marginal opportunity cost and of farm wife's education was less than marginal opportunity cost (not significantly) implies that acquiring education with the anticipation

of employing its services in own-farm work is an economically sound decision in Iowa. However, for the North Carolina and Oklahoma farms, the marginal product of husband's and wife's education was significantly below marginal opportunity cost. Thus, the services of additional education of husbands and wives in these two states should be allocated to nonfarm work. In the future, as size of the North Carolina and Oklahoma farms increases and technology of farm production becomes more complex, the marginal productivity of education relative to marginal opportunity cost can be expected to increase.

Agricultural extension agent time is one component of the human time input in U.S. agricultural production, and the results showed that the marginal products of extension were huge (in excess of $1,000 annually per day). The size of these marginal products suggests that the rate of return on investment of federal and state funds in agricultural extension manpower compares favorably with alternative uses of these funds. Thus, perhaps we should proceed more slowly in reducing in real and absolute terms federal and state appropriations for agricultural extension. Furthermore, as extension data on time allocation become available that are equal in quality to the pre-1960 data, future research on the productivity of agricultural extension will be facilitated.

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Appendix

Sources and Derivation of Labor and Education Variables

The number of days worked by hired labor per farm is derived as annual expenditures on hired labor (U.S. Dep. of Commerce 1967, table 9) deflated by the average daily wage rate for hired farm labor without board and room in 1964 (USDA 1965).

Farm husband's (wife's) man- (woman-) days per year of own-farm work are derived from weekly hours worked on farms by farm operators (nonoperator farm household members) (U.S. Dep. of Commerce 1967, county table 7). Several adjustments were made to convert the reported hours to equivalent annual days of work. First, the reported hours were adjusted to a common enumeration data; second, regression analysis followed by prediction was used to separate weekly hours of farm work by wives from hours of farm work by other nonoperator household members; and third, weekly hours were inflated by a state specific factor to make adjusted reported hours equal to average weekly hours on an annual basis. Finally, average weekly hours were converted to annual man- (woman-) days by multiplying by fifty-two weeks per year and dividing by 7.8 (6.9) hours per day. The adjustments factors for enumeration date and mean weekly hours per year were derived from unpublished USDA regional data based upon the 1966 Pesticide and General Farm Survey (USDA 1968). The factor for converting annual hours to annual days is the national average number of hours per day that farm operators (farm wives) worked at nonfarm jobs in 1965 for those who worked at nonfarm jobs (U.S. Dep. of Commerce 1968, table 16).

Farm husband's man-days of off-farm work per year equals the aggregate number of days that farm operators worked off own-farm on another farm or at nonfarm work during the census year (U.S. Dep. of Commerce 1967, county table 7) deflated by the census number of farm operators.

Wife's woman-days of off-farm work per year equal the aggregate number of days that nonoperator household members worked off the farm at nonfarm work deflated by the census number of farms (U.S. Dep. of Commerce 1967, county table 7).

The expected wage rate per day for off-farm work by farm husband (wife) is the estimated aggregate wage and salary income of farm operators (nonoperator household members) divided by the aggregate number of days of off-(non) farm work by farm operators (nonoperator household members) (U.S. Dep. of Commerce 1967, county table 7). Estimated aggregate wage and salary income of nonoperator household members is derived as total income of nonoperator members from sources other than farm operated (U.S. Dep. of Commerce 1967, county table 7) multiplied by the share that wage and salary income is of the total income from sources other than farm operated for this group at the state level (U.S. Dep. of Commerce 1967, state table 17). Estimated aggregate wage and salary income of farm operators is total wage and salary income of all farm household members minus estimated wage and salary income of nonoperator household members.

The level of education of farm husband (wife) is the income weighted average number of years of schooling completed for farm operators (nonoperator persons $\geq$ 25 years of age). The number of farm operators (nonoperator persons $\geq$ 25 years of age) in seven schooling completion classes (U.S. Dep. of Commerce 1967, county table 7) were weighted by 1959 mean incomes by schooling completion classes (Denison, table I-4, p. 223).

The Productivity and Allocation of Research: U.S. Agricultural Experiment Stations

Maury Bredahl and Willis Peterson

In this paper are presented estimates of the marginal products and internal rates of return to investment in agricultural research by commodity groups (cash grains, poultry, dairy, and livestock). The results are reported both in terms of national aggregates and on a state-by-state basis. Internal rates of return for the country as a whole range from 36% to 46%. At the state level the evidence suggests that the payoff to research is greatest for the commodities with the largest absolute value of output.

Key words: agricultural research expenditures, allocation, productivity.

The evidence forthcoming from a number of studies supports the hypothesis that investment in agricultural research in the United States has paid off with relatively high rates of return (Schultz; Griliches 1958, 1964; Peterson 1967; Evenson; Schmitz and Seckler). However, relatively little is known about the efficiency of the allocation of agricultural research. If there are differences in the rates of return to the various kinds of research, then the overall rate of return (for a given level of investment) could be increased by reallocating some research resources from the low to the relatively high return activities.

The main purpose of this article is to present estimates of the marginal products and rates of return to the four major categories of agricultural research conducted by U.S. agricultural experiment stations: cash grains, poultry, dairy, and livestock. Because research expenditures in time t will affect current and future output, estimation methods and interpretation of results must consider the lagged effect of research on output. This paper attempts to measure the long-run effect of research on output and corresponding rates of return.

The Model

We utilize aggregate agricultural production functions with research as a separate independent variable to estimate the marginal products of research. The production function approach affords an estimate of the effect of research on agricultural output and enables one to compute marginal (as opposed to average) rates of return.

The relationship of output, conventional inputs, and research is expressed in the standard Cobb-Douglas production function format.[1] The hypothesized relationship is written as

$$(1) \qquad Y_{hit} = A_i \prod_{j=1}^{p} X_{hijt}{}^{\beta_{ij}} \prod_{l=0}^{T} R_{hit-l}{}^{\gamma_l} e^{\epsilon_{hit}} ,$$

where Y_{hit} = hth observation output of ith commodity in year t, X_{hijt} = hth observation jth input in the production of ith commodity in year t, and $R_{hi,t-l}$ = hth observation research applicable to the ith commodity in the $t - l$th time period. The coefficient on research (γ_l) varies according to the date of the research input. Moving forward from year t, γ would first increase because of a lag in utilization of research but then decrease as current research becomes less related to future technology and also because of the depreciation of knowledge.

The model implies that the marginal pro-

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[1] The use of a Cobb-Douglas production function implies unitary elasticity of substitution between inputs. Shatava reports an estimated elasticity of substitution of 1.126 from the regression of the log of the value added per unit of labor and log of the wage for hired farm labor (U.S. Dep. of Commerce 1972). The estimate is not significantly different from one. However, agricultural production functions are probably not homothetic, much less homogeneous. In practice, nonhomothetic production functions are difficult to estimate; the assumed Cobb-Douglas form is for simplicity and hopefully the marginal products of research are not affected.

ductivity of research should be differentiated with respect to time. Hence, the following definitions are in order. The short-run marginal product (*SMPR*) of research is the effect of current research on current output: $SMPR_{hit} = \partial Y_{hit}/\partial R_{it} \equiv \gamma_o Y_{hit}/R_{hit}$. The long-run marginal product of research (*LMPR*) measures the effect of current research on current and future output:

$$LMPR_{hit} = \sum_{l=0}^{T} \partial Y_{hi,t+l}/\partial R_{it} \equiv \sum_{l=0}^{T} \gamma_l \; Y_{hi,t+l}/R_{hi,t+l}.$$

The hypothesized production relationship could be estimated with time-series cross-section data. Unfortunately, such data are not available; we are limited to a single-year—1969—cross section. Thus, the estimation model is specified as

$$(2) \qquad Y_{hi} = A'_i \prod_{j=1}^{p} X_{hij}^{b_{ij}} \, R_{hi} \, e^{u_{hi}}.$$

Because a single-year cross section is utilized to estimate the parameters of the time-series cross-sectional model, the consequence of omitting lagged research expenditures should be determined. If we assume that research has been increasing at a constant rate over time such that $R_{t-1} = kR_t$, where $0 < k < 1$, the model can be simplified to[2]

$$\ln Y_{hit} = \ln A_i + \sum_{j=1}^{p} \beta_{ij} \ln X_{hij} + \ln R_{hit}\Big(\sum_{l=0}^{T} \gamma_l\Big) + \ln K\Big(\sum_{l=0}^{T} l\gamma_l\Big).$$

The expected values of the coefficients of the estimation model are $E(\ln \hat{A}'_i) = \ln A_i + C$, $E(\hat{b}_{ij}) = \beta_{ij}$, and $E(\hat{\delta}) = \sum_{l=0}^{T} \gamma_l$. Therefore, utilizing current year research as the research variable biases the expected value of the estimated constant term ($\hat{A}'$) of the production function upward but does not bias the expected value of the estimated coefficients of the conventional inputs (X_{ij}). More important, what effect does the misspecification of the model have on the expected value of the estimated marginal production of research?

The expected value of the estimated marginal product of research (evaluated at geometric means) is $E(\partial Y_t/\partial R_t) = E(\hat{\delta}) \cdot (\bar{Y}_t/R_t)$. Substituting and expanding, $E(\partial Y_t/\partial R_t) = \gamma_o(\bar{Y}_t/\bar{R}_t) + \ldots + \gamma_l(\bar{Y}_t/\bar{R}_t)$. This measure is clearly larger than the defined short-run marginal product of research.

The relationship to the long-run marginal product of research may be determined. Recalling $R_{t-1} = kR_t$, $k < 1$,

$$LMPR = \gamma_o \left(\frac{\bar{Y}_t}{\bar{R}_t}\right) + \gamma_1 \left(\frac{\bar{Y}_t}{k\bar{R}_t}\right) + \ldots + \gamma_l\left(\frac{\bar{Y}_t}{k^l\bar{R}_t}\right).$$

The expected value of the estimated marginal product of research is clearly less than the long-run marginal product of research because each $\bar{R}_t$ after the first term in the *LMPR* definition is multiplied by a constant which is less than one. The marginal product of research (*MPR*) in time t is indicated by

$$LMPR = \gamma_o \left(\frac{\bar{Y}_t}{\bar{R}_t}\right) + \gamma_1 \left(\frac{\bar{Y}_{t+1}}{\bar{R}_t}\right) + \ldots + \gamma_l \left(\frac{\bar{Y}_{t+l}}{\bar{R}_t}\right).$$

The relationship of the expected value of the estimated *MPR* and the "true" *MPR* is dependent on the level of future research and conventional input use. To the extent that these figures increase in a manner that increases the average product of research, the estimated value of *MPR* underestimates its "true" value. If so, then the estimated marginal products of research obtained in this study can be regarded as lower bound estimates of the *LMPR*.[4]

[2] The assumption of an identically constant rate of increase in research for each state is somewhat unrealistic. However, essentially similar results are obtained if k is randomly distributed with some mean $\bar{k}$ and variance σ_k. The mean might be interpreted as the national average rate of growth in research expenditures with the growth rate of the states distributed about the national average rate of growth (see Bredahl).

[3] The geometric mean values of output and research are $\bar{Y}_t$ and $\bar{R}_t$, respectively.

[4] The functional form of the research branch determines the interpretation of the estimated results. The ith production function may be written as

$$Y_{it} = A_i \prod_{j=1}^{p} X_{ijt}^{\beta_{ij}} R'^{\gamma}_{it},$$

where R'_{it} is interpreted as the "stock of research" at time t. If the research measure is a linear function of past research $R'_{it} = \delta_o R_t + \delta_1 R_{t-1} + \ldots + \delta_l R_{t-l}$ and if $R_t = kR_{t-1}$, substituting and expanding yields $R'_{it} = \delta_o R_t + \delta_1 kR_t + \ldots + \delta_l k^l R_t$. This model also implies that $\hat{\gamma}$ is an unbiased estimate of the marginal product of the stock of research. The specification of the research branch in this manner may lead to different methods of calculating rates of return and interpretation of the estimated marginal product of research.

The Variables and Data

Output is measured as average value of output per farm for each of four types of farms (cash grains, dairy, poultry, and livestock) as reported by the *1969 Census of Agriculture* (U.S. Dep. of Commerce 1972, 1973a, b). A farm is included in a "type of farm" classification if over 50% of its sales are of a given commodity type. These four farm types account for over 80% of all farms and sales of agricultural products in the United States. A more accurate measure of the relationship between output and its related research may be obtained if the dependent variable in each production function includes only that output that corresponds to the farm classification. For example, any livestock production that may have taken place on cash grain farms is not included in the dependent variable of the cash grains production function and vice versa. Also, constant prices are used to aggregate output in order to remove the effect of interstate price differences. More specific definitions of the four variables are presented in the appendix.

To the extent allowed by the data, the conventional inputs are selected and measured to reflect as closely as possible the output included in the dependent variables. For example, the land input in the cash grains function includes only the harvested acreage of the crops included in the output. Of course, for certain inputs it is not possible to apportion their use exactly to the output included. For example, tractors and equipment on cash grain farms no doubt are utilized in the production of other crops such as cotton in the South and West and sugar beets in the Midwest and West. In order to obtain asymptotically unbiased estimates of slope coefficients, an instrumental variable (IV) estimation technique is utilized in addition to ordinary least squares (OLS).[5] Again, interstate price differences that are not considered to reflect quality differences are removed. Specific definitions of the independent variables and data sources are presented in the appendix.

Because production decisions are made at the farm level, the farm is the proper unit of observation for the dependent and conventional independent variables. However, it is not clear that a per farm average is the correct specification for the research variable. Previous studies have utilized both per farm averages (Griliches 1964, Evenson) and state totals (Peterson 1967). Dividing total state research by number of farms obtaining a per farm average implies that the number of farms is a proxy for the number of problems faced by scientists, the greater the number of farms the greater the diversity of problems. On the other hand, the use of the state total as the research variable treats research as a public good. In this case, the research variable, which can be viewed as a proxy for the output of the experiment station, is not altered by the number of farms in the state. For example, halving the number of farms in a state should not double the measured research output of the experiment station. Certainly both specifications of the research variable have some justification. Perhaps the "true" specification lies somewhere between the two. An empirical test can be made to determine which specification comes closest to the truth.

Each of the aggregate production functions estimated in this study may be written as $\Sigma Y/n = A \prod_i (\Sigma X_i/n)^{\beta_i}(R/n^{\alpha})^{\beta_r}$, where ΣY is the sum of the appropriate output of the particular class of farms in the state, ΣX_i is the sum of the appropriate conventional inputs, R is the total appropriate research, and n is the number of farms in the particular class. If α equals one, then research per farm is the correct specification, whereas total state research is correct if α is estimated to be zero. Estimates of α are obtained from the following equation: $\ln(\Sigma Y/n) = \ln A' + \Sigma b_i \ln(\Sigma X_i/n) + b_r \ln R - c \ln(n)$. The estimated coefficient ($\hat{c}$) of the number of farms is an estimate of the product $\alpha\beta_r$. Because $\hat{b}_r$ is an estimate of β_r, $\hat{\alpha}$ is easily estimated by dividing $\hat{c}$ by $-\hat{b}_r$ and can be statistically tested for equality to one or zero. Estimates of α for each of the four production functions are cash grains, −0.123, dairy, 0.301, poultry, 0.073, and livestock, −3.720. The estimated value of α is significantly different from one in all four equations and is not significantly different from zero in the first three.[6] (The relatively large negative value for

[5] This technique is of the general form $\hat{b} = (Z'X)^{-1} Z'Y$, where Z is the matrix of instrumental variables, X is the matrix of independent variables, and Y is the column vector of the dependent variable. For each independent variable, the deviations from the mean are calculated and then rank ordered from smallest to largest. The deviates compose the X matrix and the rank ordering the Z matrix. It can be shown that b is a consistent estimator of each slope coefficient (see Durbin).

[6] The test is conducted by comparing the error sum of squares from the regressions where it is restricted to one and to zero with the error sum of squares, which is obtained when it is unrestricted.

α in the livestock equation is something of a puzzle.) The results suggest that the research per state is closer to the "true" specification than research per farm. Thus, the former is utilized in all four production functions.

State experiment station research expenditures are obtained from the *Inventory of Agricultural Research, F.Y. 1969 and 1970* (USDA 1970d). The composition of each research variable is explained in the appendix.

Regression Results

As mentioned, the possibility of errors in variables due to the inability to exactly apportion all inputs to the output measure prompted the use of the instrumental variable (IV) estimation technique to supplement ordinary least squares (OLS). The regression results obtained from the OLS and IV techniques for the four production functions are presented in tables 1 through 4.

By and large, the regression coefficients have reasonably large t-values. One exception is fertilizer in the cash grains function when the coefficient is restricted to a single value for all observations. This is somewhat unexpected in view of the importance of fertilizer in crop production. However, soybeans and wheat do not receive heavy applications of commercial fertilizer. In cash grains production, corn is by far the major fertilizer user. In order to take account of the diversity of fertilizer use stemming from differences in crops grown, the country is divided into three regions, as shown in table 1, with slope dummies on the fertilizer variable allowing the coefficient to take on different values for different regions.

Of most interest are the research coefficients. Ranging from 0.04 for cash grains to 0.10 for livestock, they bracket the 0.059 coefficient on all agricultural research obtained by Griliches from 1949–54–59 data (Griliches 1964). The 0.061 poultry research coefficient obtained here is virtually identical to the 0.062 coefficient reported by Peterson from 1959 data (Peterson 1967).

Table 1. Estimates of the Cash Grains Production Function

Inputs	OLS	IV
Fertilizer[a]		
Southeast	0.011 (0.2)	0.038 (0.8)
Corn Belt	0.111 (2.3)	0.137 (2.8)
Other	0.071 (1.9)	0.102 (2.3)
Labor	0.234 (3.5)	0.251 (3.2)
Land	0.207 (2.7)	0.192 (2.0)
Chemicals	0.074 (2.1)	0.081 (1.9)
Seed	0.164 (2.3)	0.132 (1.5)
Machinery	0.455 (3.2)	0.447 (2.4)
Research	0.038 (1.5)	0.041 (1.6)
$\bar{R}^2$	0.95	
Sum of coefficients[b]	1.18	1.14

Note: Figures in parentheses are t-values. 41 observations.
[a] The reference dummy is the group of states not included in the southeast and corn belt. The OLS t-values on the fertilizer slope dummies are: southeast, −3.0; corn belt, 1.9; and the IV t-values are: southeast, −3.1; corn belt, 1.6.
[b] For cash grains the sum of coefficients is computed from the regression where fertilizer is restricted to a single coefficient for all observations. In all cases the sum of coefficients excludes the research variable.

Table 2. Estimates of the Dairy Production Function

Inputs	OLS	IV
Dairy cattle	0.204 (3.3)	0.177 (2.5)
Labor	0.548 (8.4)	0.632 (7.9)
Land and buildings	0.062 (2.8)	0.077 (2.8)
Pasture	0.055 (2.3)	0.046 (1.8)
Feed	0.209 (4.2)	0.151 (2.3)
Research	0.042 (2.7)	0.054 (2.9)
$\bar{R}^2$	0.99	
Sum of coefficients	1.08	1.08

Note: Figures in parentheses are t-values. 48 observations

Marginal Products and Rates of Return

The estimated coefficients of the IV estimates are utilized to compute the marginal products of experiment station research. The research variable is measured as research per state while output is measured as output per farm. Thus, the estimated marginal product of research is measured on a "per farm" basis. To obtain an estimate of "per state" marginal

Table 3. Estimates of the Poultry Production Function

Inputs	OLS	IV
Feed	0.591 (5.4)	0.530 (4.1)
Poultry purchased	0.261 (2.6)	0.282 (2.5)
Land and buildings	0.145 (4.0)	0.123 (2.9)
Labor	0.163 (2.4)	0.185 (2.3)
Research	0.071 (1.8)	0.061 (1.5)
$\bar{R}^2$	0.93	
Sum of coefficients	1.16	1.12

Note: Figures in parentheses are t-values. 48 observations.

Table 4. Estimates of the Livestock Production Function

Inputs	OLS	IV
Feed	0.470 (4.6)	0.547 (4.6)
Land and buildings	0.290 (4.0)	0.261 (3.3)
Labor	0.147 (1.2)	0.067 (0.7)
Livestock	0.137 (1.4)	0.137 (1.2)
Research	0.109 (4.2)	0.099 (3.7)
$\bar{R}^2$	0.92	
Sum of coefficients	1.04	1.01

Note: Figures in parentheses are t-values. 46 observations.

products, the "per farm" estimate is multiplied by the number of farms.

Estimates of national "average" marginal products of research are obtained by using the geometric mean levels of inputs and outputs and the arithmetic average number of farms. The computed marginal product is $M\hat{P}R_i = \hat{b}_{ri}\bar{n}_i(\bar{Y}_i/\bar{R}_i)$. These estimates are given in table 5.

The estimated marginal product of research approximates the long-run marginal product of research, that is, the expected total returns from $1 invested in 1969. Evenson's work suggests the lag structure of agricultural research resembles that of an inverted "V." The estimated marginal products are approximations of the total area under the inverted "V" lag structure. The calculation of internal rates of return requires that the future returns be discounted. The internal rate of return is approximated by the following:[7]

$$\sum_{t=0}^{T}(\partial Y_{t+i}/\partial R_t)/(1 + IRR)^t - 1 = 0.$$

The calculated internal rates of return are dependent on the mean lag of the lag structure.

According to Evenson's results, the mean lag (high point of the inverted "V") for all agricultural experiment station research is in the neighborhood of six to seven years. However, estimates of the mean lag of research of the commodity groups of interest in this paper are not available. One might reasonably expect that the lag is somewhat shorter for crops where the possibility exists for large numbers of research trials to be carried on simultaneously than for livestock where biological processes probably constrain the pace of research more severely. For lack of better information, we assume the mean lag to be a bit shorter than average for cash grains, about average for poultry and dairy, and a shade above average for livestock, as shown in column two of table 5.[8]

In order to arrive at conservative estimates of rates of return, the marginal product figures in table 5 are divided by a factor of three to take account of public extension and private research.[9] This procedure is likely to bias the estimated rates of return downward for two reasons. First, it is unlikely that research results would go unnoticed in the absence of public extension or that the extension lags are this long. The rate of return to extension should be computed separately on the basis of how much it speeds up the adoption of the new technology (see Huffman). Second, the cost of private research must already be included in the prices of purchased inputs. Thus, we are in effect double-counting the cost of private research. However, it is still necessary to take account of private research because the coefficients on public research probably are picking up the excess of social over private returns to private research (see Peterson 1976).

If the lags that are specified in table 5 are reasonably accurate, at least in relative terms, the internal rates of return (IRR) of these four major categories of research are not grossly different. On the basis of this evidence, one might conclude that from a national standpoint agricultural experiment station research is being allocated fairly efficiently, at least across these four major categories.[10] Of course, if

Table 5. Marginal Products and Marginal Internal Rates of Return to Experiment Station Research

	Marginal Products ($)	Assumed Lag (years)	IRR (%)
Cash grains	14.09	5	36
Poultry	19.58	6	37
Dairy	25.93	6	43
Livestock	41.76	7	46

[7] The internal rate of return in this case is that rate of interest that makes the discounted returns of $1 of research invested in year t equal to the $1.

[8] One might argue that dairy and livestock should have about the same mean lag. However, the beef, hog, and sheep research that make up the livestock category is somewhat more oriented towards breeding work than is dairy research. Breeding research would seem to have a longer lag than research, which bears upon management, such as feeding and health practices.

[9] In recent years extension expenditures have been about equal to research. The magnitude of private research also is believed to be about equal to public research.

[10] Further support of the seemingly efficient allocation of research expenditures may be found by comparing the estimated marginal products of research assuming identical lag structures. In this case

evidence should come to light that suggests that the cash grains lag is really longer than that specified and/or the livestock lag shorter, then the estimated rates of return would diverge even more. Also, it is evident that the marginal social rates of return to investment in these four categories of research are relatively high, especially in view of the downward biases mentioned above.

In the context of a Cobb-Douglas production function, the marginal product of research depends upon two factors: the coefficient on the research variable (the production elasticity) and the average product of research, i.e., dollars of output per dollar of research.[11] Experiment stations that exhibit above average production elasticities on research, say, because of more competent and productive research workers and/or because of more dollars of output per dollar of research, will in turn enjoy higher marginal products and rates of return to research than their less productive or smaller average product counterparts.

In order to test for possible differences in the production elasticities of research across states, the sample for each research category is divided into three groups according to the size of their average products of research, with each group having about equal numbers of observations. The same production functions are then run with slope dummies on the research variables allowing the research variable to take on a different value for each group. (The smallest average product states constitute the reference dummy.) The coefficients and t-ratios on the slope dummies are presented in table 6. As shown, none of the slope dummies are significantly different from zero.

These results are consistent with the hypothesis that the coefficients on the research variables are not significantly different between comparable departments or between experiment stations. This does not mean that research workers are equally productive across departments or experiment stations. What it may imply is that the market for research workers is functioning rather efficiently. Workers with above average productivity receive above average compensation, and vice versa.

Table 6. Research Slope Dummies by Average Product Groups (IV Estimates)

	Middle Third	Highest Third
Cash grains	0.004 (0.6)	−0.010 (−0.8)
Poultry	−0.008 (−0.7)	−0.009 (−0.7)
Dairy	0.001 (0.1)	0.001 (0.3)
Livestock	0.018 (0.3)	0.021 (0.9)

Note: Figures in parentheses are t-ratios.

The results presented in table 6 also are consistent with the hypothesis of constant returns to scale of departments or research areas as denoted by the four categories of research. Except for dairy, the absolute size of the research establishment is positively correlated with the average product of research.[12] If there are economies of scale, then the larger departments or research areas should exhibit larger production elasticities, which they do not.

If the production elasticities of the departments corresponding to the four commodity groups do not differ by size of average product, then differences in average products between states should reflect differences in marginal products and rates of return. Using the research coefficients shown in table 5 (IV estimates), the marginal products of the four research categories for each state are presented in table 7. (These figures are not adjusted for extension and private research.)

It is evident from the marginal product figures in table 7 that substantial differences exist between states in the rates of return to investment in each of the four areas. By and large, the rates of return are highest in those states where the product makes up a large share of the agricultural output of the state and is large relative to the research input. For example, Illinois leads in the marginal product

equality of marginal products is a sufficient condition for equality of internal rates of return. The variance of the MPR's is approximated by $\mathrm{var}(n_i b_i \hat{Y}_i/\hat{R}_i) \simeq n_i^2(\bar{Y}_i/\bar{R}_i)^2 \ \mathrm{var}(\hat{b}_i)$. These estimated variances may be used to construct confidence intervals of the difference of the difference of any two marginal products (see Miller): $MPR_i - MPR_j \pm t_{(n-k/1-\alpha/2)} [\hat{S}^2_{MPR_i} + \hat{S}^2_{MPR_j}]^{\frac{1}{2}}$. For all pairwise comparisons, the confidence interval contained zero; therefore, the marginal products cannot be judged to be significantly different.

[11] The same holds true for the so-called "index number" approach of evaluating research. In this case, the "k" is comparable to the production elasticity of research and the absolute value of output is comparable to the average product (see Griliches 1958 and Peterson 1967).

[12] The average research expenditure per station for each of the four research categories by the three average product groups follow (thousands of dollars):

	Low	Middle	High
Cash grains	258	413	823
Poultry	202	312	409
Dairy	462	417	438
Livestock	514	616	1,061

Table 7. Marginal Products of Research, the Several Production Functions, by State

	Production Function			
State	Dairy	Cash Grains	Poultry	Livestock
Maine	$ 7.21[a]	n.a.[b]	$26.97	$ 3.72
New Hampshire	9.80	n.a.	3.40	17.15
Vermont	39.08	n.a.	2.36	2.04
Massachusetts	14.73	n.a.	4.82	n.a.
Rhode Island	2.29	n.a.	1.26	n.a.
Connecticut	18.12	n.a.	13.07	3.39
New York	33.23	1.07	10.21	5.61
New Jersey	8.22	1.87	4.18	3.33
Pennsylvania	24.79	3.64	12.26	3.05
Ohio	15.96	12.52	9.40	15.85
Indiana	12.64	14.60	19.01	32.12
Illinois	9.19	40.14	12.63	38.49
Michigan	11.48	7.32	8.10	11.28
Wisconsin	56.00	2.67	8.41	12.50
Minnesota	51.11	13.15	18.20	75.55
Iowa	16.57	10.62	11.19	60.13
Missouri	8.42	12.30	14.12	53.24
North Dakota	20.27	18.42	2.79	37.24
South Dakota	13.31	6.85	4.18	37.11
Nebraska	4.00	9.45	2.26	28.06
Kansas	6.70	11.25	2.55	52.39
Delaware	2.37	4.21	16.74	2.14
Maryland	8.35	5.00	13.54	5.20
Virginia	10.69	2.57	8.91	9.58
West Virginia	14.24	0.48	8.25	13.08
North Carolina	6.46	3.81	38.71	12.10
South Carolina	7.73	3.84	18.06	6.11
Georgia	5.33	1.92	36.65	14.02
Florida	6.57	1.52	25.22	1.66
Kentucky	15.76	6.20	8.15	16.88
Tennessee	6.33	5.74	17.29	7.23
Alabama	6.14	2.06	48.26	10.39
Mississippi	10.18	8.62	41.01	14.43
Arkansas	4.29	19.83	66.40	8.48
Louisiana	2.58	7.04	6.56	1.88
Oklahoma	10.51	7.40	10.94	24.26
Texas	30.11	18.91	21.05	43.26
Montana	6.71	13.56	2.82	15.65
Idaho	23.31[a]	6.77	3.38	19.56
Wyoming	2.13	2.36	0.82	11.21
Colorado	41.45	16.73	9.73	61.97
New Mexico	15.26	6.52	3.81	29.37
Arizona	7.38	2.14	5.23	11.01
Utah	7.38	2.12	9.70	13.80
Nevada	3.93	n.a.	1.43	10.18
Washington	11.52	9.88	4.42	9.10
Oregon	7.29	4.60	9.28	8.94
California	20.48	6.17	19.32	18.22

[a] The marginal products of research are not adjusted for private research and extension expenditures. To accomplish this correction, each marginal production is divided by 3. Average products may be calculated if the partial production elasticity is known. The partial production elasticities are: dairy, 0.054; cash grains, 0.041; poultry, 0.061; and livestock, 0.099. The average product is derived by dividing the marginal product by the partial production elasticity.

[b] All states with marginal products indicated by the not applicable (n.a.) notation are not included in the sample, i.e., did not have farms classified as cash grain farms, etc.; therefore, estimates of marginal products may not be calculated.

of cash grains research, Arkansas in poultry, Wisconsin in dairy, and Minnesota in livestock.

Also, it appears that some differences exist in the rates of return within states between the four commodity groups, although in this case one should be mindful of possible differences in lags. But when marginal product differences reach the magnitude of ten to twenty times, it is unlikely that differences in lags can equalize rates of return. Also, there are a number of states where the marginal products are higher for cash grains and poultry, which are likely to have the shortest lags. Again within states, the marginal products (and rates of return) for the most part turn out to be the highest for the large and important product categories in each state. For example, livestock research in Kansas appears to have a substantially higher payoff than poultry research, whereas the opposite is true in Arkansas.

In viewing these results, one should be mindful of possible spillover effects of research between states. It seems reasonable to believe that states having the largest departments or research areas are net exporters of research results. If so, this would have the effect of biasing the estimated marginal products of the small stations upward, while the marginal products of the large stations would be biased downward. (This could explain the apparent equality of coefficients between large and small departments.) The possibility of such a bias suggests that the measured differences between the large and small marginal products may be even greater than the results indicate because the highest marginal products tend to be associated with the largest departments.

The general conclusion that the absolute value of the related output has an important bearing on the rate of return to research is, of course, not new. Griliches demonstrated the importance of the value of related output in his hybrid corn study by comparing the rate of return of hybrid corn research to that of sorghum research (Griliches 1958). The figures in table 7 provide a more comprehensive and detailed picture of the payoff matrix.

Of course, the figures in table 7 should be viewed as general orders of magnitude rather than exact, accurate-to-the-penny marginal products. Because the production elasticities are averages over groups of departments or research areas, it certainly would be possible for a given department staffed by very compe-

tent and productive people to exhibit an above average production elasticity. Even if such a department was associated with a below average output per dollar of research (average product), its marginal product may equal or exceed a less productive department that enjoys a higher average product. Certainly good judgment and common sense still must be used in research allocation; the figures in table 7 are intended to complement rather than serve as a substitute for good judgment.

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Appendix

Measuring Output and Inputs

This appendix does not detail the construction of each variable for each production function. Rather, the discussion is intended to present the general point of view adopted for variable construction and to illustrate the techniques utilized. Because the estimated functional relationships are advertised to be aggregate production functions, variables are constructed to reflect variation in physical quantities (free of price variation) rather than total sales or cost measures. Although considerable effort was made to obtain accurate measures of the variables, one should be mindful of possible measurement errors in the data itself.

Output. Output measures are constructed to reflect variation in physical quantities produced. The constructed output measures of cash grains and dairy reflect the two general approaches to measure output. Cash grains = $\Sigma_i Y_i \bar{P}_i$, where Y_i is bushels of each type of cash grain produced (U.S. Dep. of Commerce 1972), and $\bar{P}_i$ is national average price of each type of cash grain (USDA 1970a).

The first step in measuring dairy output was the construction of an index reflecting price variation: $Index_k = \Sigma_i (S_{ik}/\Sigma_i S_{ik})(\bar{P}_i/P_{ik})$, where S_{ik} is sales of ith dairy product in kth state (USDA 1970b), $\bar{P}_i$ is national price of ith dairy product (USDA 1970a), and P_{ik} is state average price of ith dairy product in kth state (USDA 1970a). The measured dairy output was constructed via $Dairy\ Output_k = (Sales_k)(Index_k)$, where $Sales_k$ is sales of dairy products in kth state (U.S. Dep. of Commerce 1972).

The poultry output variable is formed in the same manner as the dairy output variable.

Livestock output is computed from $Output_k = \Sigma_i Value_{ik}(No.\ Sold_{ik})$, where $Value_{ik}$ is average value of production per animal of ith livestock type in kth state (USDA 1970b), and $No.\ Sold_{ik}$ is number of animals sold of each livestock type in kth state (U.S. Dep. of Commerce 1972).

Inputs. The labor variable for all production functions was constructed in the following manner: $L_1 = P_o L_o + P_u L_u + P_h H/W$, where L_1 is calculated man-days of labor used in production of products agreeing with type of farm classification (U.S. Dep. of Commerce 1973b), P_o, P_u, and P_h are reported proportion of total operator, unpaid (family), and hired labor used in production of products agreeing with the type of farm classification (U.S. Dep. of

Commerce 1973b), L_o and L_u are total man-days of operator and family labor (U.S. Dep. of Commerce 1972), H is dollars expended for hired and contract labor (U.S. Dep. of Commerce 1972), and W is composite wage rate (USDA 1969). The variation of wage rates was believed to reflect differences in the quality of labor. Hence, the final labor variable was measured by $L_2 = (W_k/\overline{W})\ L_1$, where W_k is the kth state average composite wage (USDA 1969), and $\overline{W}$ is national average composite wage (USDA 1969).

The land variable is very difficult to measure. For crop production, harvested acres (U.S. Dep. of Commerce 1972) was chosen as the appropriate variable. This variable does not reflect variation in land quality. However, the bias of this omitted variable may be determined; the bias resulting from the use of an inappropriate quality adjustment is not known.

Pasture is a direct input into the dairy and livestock production function measured as pastured acres (U.S. Dep. of Commerce 1972). For poultry production land serves only as a site of production. The livestock, dairy, and poultry functions must include some measure of capital in the form of buildings. The measure used is *Buildings and Capital*$_k$ = $(Value_k)(\overline{L}/L_k)$, where $Value_k$ is market value of land and buildings in kth state (U.S. Dep. of Commerce 1972), $\overline{L}$ is national average per acre value of land (USDA 1970b), and L_k is the kth state average per acre value of land (USDA 1970b).

The research variable is the sum of expenditures for products agreeing with this type of farm classification. For example, the livestock research variable includes research for sheep, beef, swine, and pasture; dairy includes dairy and pasture research (USDA 1970d).

The other variables are too numerous to detail. Therefore, a very brief description of the other variables in each production function follows. For cash grains, fertilizer is the tons of fertilizer applied adjusted by an index expressing the variation in nutrient content of the fertilizer (U.S. Dep. of Commerce 1973b). Chemicals is measured as the dollars of agricultural pesticides applied deflated by prices of major pesticides (U.S. Dep. of Commerce 1972 USDA 1970c). Seed is the dollars of seed purchased (U.S. Dep. of Commerce 1972). Machinery is the service flow of machinery plus the deflated expenditures for energy sources plus hired machinery and customwork (U.S. Dep. of Commerce 1972). For dairy, dairy cattle is number of lactating dairy cows adjusted by an index of dairy cow prices (U.S. Dep. of Commerce 1972, USDA 1970b). Feed is the dollars of feed purchased and produced on the farm adjusted for regional price differences (U.S. Dep. of Commerce 1972, USDA 1970a). For poultry, feed is measured by dollars expended for feed adjusted for regional price differences. (U.S. Dep. of Commerce 1972, USDA 1970a). Poultry purchased is the purchases of poults and chicks adjusted for regional price differences (U.S. Dep. of Commerce 1972, USDA 1970a). For livestock, feed is the dollars of feed purchased and produced on the farm adjusted for regional price differences (U.S. Dep. of Commerce 1972, USDA 1970a). Livestock is the service flow of breeding stock weighted by on-farm price of each type plus the value of purchased livestock (U.S. Dep. of Commerce 1972, USDA 1970a).

Impacts of Market-Share Patterns on Marketing Firm Costs

Ronald Raikes and Arnold Heubrock

Uniform market-share patterns have been assumed in specifying cost functions for assembly or delivery operations. A more realistic assumption is that market share decreases with distance from the plant. Procedures for specifying assembly or delivery-cost functions for alternative linear market-share patterns and for determining impacts of changes in market-share patterns on costs and related results are developed and applied in an analysis of anhydrous ammonia retailing. These procedures permit more accurate estimates of cost-volume relationships and make it possible to address questions about how firms should attempt to achieve volume increases.

Key words: assembly, cost functions, delivery, fertilizer retailing, market share.

Many marketing firms have in addition to their in-plant operations assembly or delivery operations that require trips from the plant to each supply or demand point. A common procedure for measuring cost-output relationships for these firms is to estimate cost functions for the in-plant operation and for the assembly operation or the delivery operation or both and then to sum these functions to obtain a cost function for the combined operations. To specify a cost function for the assembly or delivery operation, an assumption is needed about the firm's market-share pattern. The market-share pattern defines the firm's trade area (i.e., the area in which the firm has a positive market share) and shows the firm's percentage market share at each point within its trade area. In earlier studies, it has been assumed that the firm's percentage market share is the same at each point within its trade area (e.g., studies by Anderson, Jorgensen, and Nelson; Araji and Walsh; and Mikes, Fletcher, and Futrell). This assumption has been popular not because it has been verified in empirical studies but because a procedure for incorporating other and perhaps more realistic assumptions about the market-share pattern into the specification of assembly and delivery-cost functions has not been developed. The development of a procedure for incorporating other market-share assumptions would make it possible to obtain more accurate estimates of cost-output relationships and to determine the impacts of changes in market-share patterns on firm costs.

In this article, a procedure for incorporating alternative assumptions about the firm's market-share pattern into the specification of assembly and delivery-cost functions is developed, qualitative impacts of changes in the market-share pattern on firm costs and other related results are shown, and results of an empirical study of impacts of changes in market-share patterns on costs of retailing anhydrous ammonia fertilizer are presented. Although the discussion focuses on impacts of market-share patterns on delivery costs, the application of the analysis to impacts of market-share patterns on assembly costs requires only a reinterpretation of some of the variables and parameters.

Delivery Cost Functions for Alternative Market-Share Patterns

To begin the analysis, some assumptions about a firm's delivery operation are introduced and a delivery-cost identity is specified. Next, a delivery-cost function is derived for a uniform market-share pattern. Then, a more general assumption about the market-share pattern is introduced, and a delivery-cost function for this market-share pattern is derived.

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Delivery-Cost Identity

To develop a delivery-cost identity, consider a firm that manufactures or processes a product and delivers the product from its plant to customers. Assume that the length of the delivery season is fixed, that a single delivery technology exists, that i different types of equipment are required for each delivery, and that the volume per delivery, number of stops per delivery, and average travel speed are constant. Then total annual delivery costs (TDC) for the firm may be expressed as

$$(1) \qquad TDC = (b_0 + b_1\bar{D})Q + \sum_i F_i N_i,$$

where

$$(2) \qquad N_i \geq (g_{0i} + g_{1i}\bar{D})Q/H_i,$$

and b_0 is the constant cost per unit of product associated with loading, unloading, and waiting; b_1 is the cost per unit of product per mile traveled, plus return, including operator labor and equipment operating costs; $\bar{D}$ is the average one-way road distance traveled per unit of product delivered; Q is units of product delivered per season; F is the annual cost of owning or renting a unit; N is the number of units; g_0 is the constant time requirement per unit of product delivered; g_1 is the time requirement per unit of product delivered per mile, plus return; H is hours available per season; and i is the type of delivery equipment. The first term on the right-hand side of equation (1) may be interpreted as the total variable delivery costs and the second term as the total fixed delivery cost.

If fractional delivery units may be added to the firm (e.g., if the firm can rent a unit for part of the season), then inequality (2) may be changed to an equation, and this equation may be used to eliminate N_i from equation (1):

$$(3) \quad TDC = (b_0 + b_1\bar{D})Q + \sum_i F_i)g_{0i} + g_{1i}\bar{D})Q/H_i.$$

A delivery-cost function can be obtained from equation (3) by eliminating $\bar{D}$. But to eliminate $\bar{D}$, some additional assumptions must be introduced concerning the nature of the road system, demand density, and market share.[1] Two models are considered. In both, it is assumed that the firm's trade area is served by a square grid road system and that demand density is uniform throughout the firm's trade area. In model I, the market share is assumed uniform throughout the firm's trade area. In model II, market share is assumed to be a linear function of distance from the plant.

[1] Demand density is the quantity of product demanded per unit area per time period, e.g., the tons demanded per square mile per season.

Model I: Uniform Market-Share Pattern

A delivery-cost function for model I can be derived by first expressing $\bar{D}$ as a function of quantity delivered, density, and the uniform market share and then using this expression to replace $\bar{D}$ in equation (3).

Following French, an expression relating $\bar{D}$ to quantity delivered, density, and the uniform market share may be derived as follows. With a square grid road system, the least-cost shape of the firm's trade area is a square tilted 45° to the road network. Let R represent the road distance in miles from the plant to the boundary of the firm's trade area. The firm's market share (S) at a point r road miles from the plant is given by $S = M$, where $0 \leq M \leq 1$, if $r \leq R$, and by $S = 0$ if $r > R$. This market-share pattern is depicted graphically by the solid lines in figure 1a. Let P represent the uniform demand density. The quantity of product delivered in a trade area that extends R miles from the plant to the boundary of the trade area is

$$(4) \qquad Q = 2PMR^2,$$

and average hauling distance is

$$(5) \quad \bar{D}_I = \text{total ton miles/total tons delivered} = (4PM/Q) \int_0^R \int_0^{R-x} (x + y)dydx = 2R/3.$$

Equation (4) may be used to eliminate R from equation (5) so that average hauling distance is given by

$$(6) \qquad \bar{D}_I = 0.4714(Q/PM)^{\frac{1}{2}}.$$

Finally, the long-run total delivery cost function for model I is obtained by substituting equation (6) into equation (3):

$$(7) \quad LTDC_I = [b_0 + B_I Q^{\frac{1}{2}} + \sum_i F_i(g_{0i} + G_{Ii}Q^{\frac{1}{2}})/H_i]Q,$$

where $B_I = (0.4714)b_1(PM)^{-\frac{1}{2}}$, and $G_{Ii} = g_{1i}B_I/b_1$. Equation (7) might be termed a restricted long-run, delivery-cost function; it is long run because the amount of delivery equipment is allowed to vary, but it is restricted because only one delivery technology is considered.

Equation (7) may be used to obtain, for a

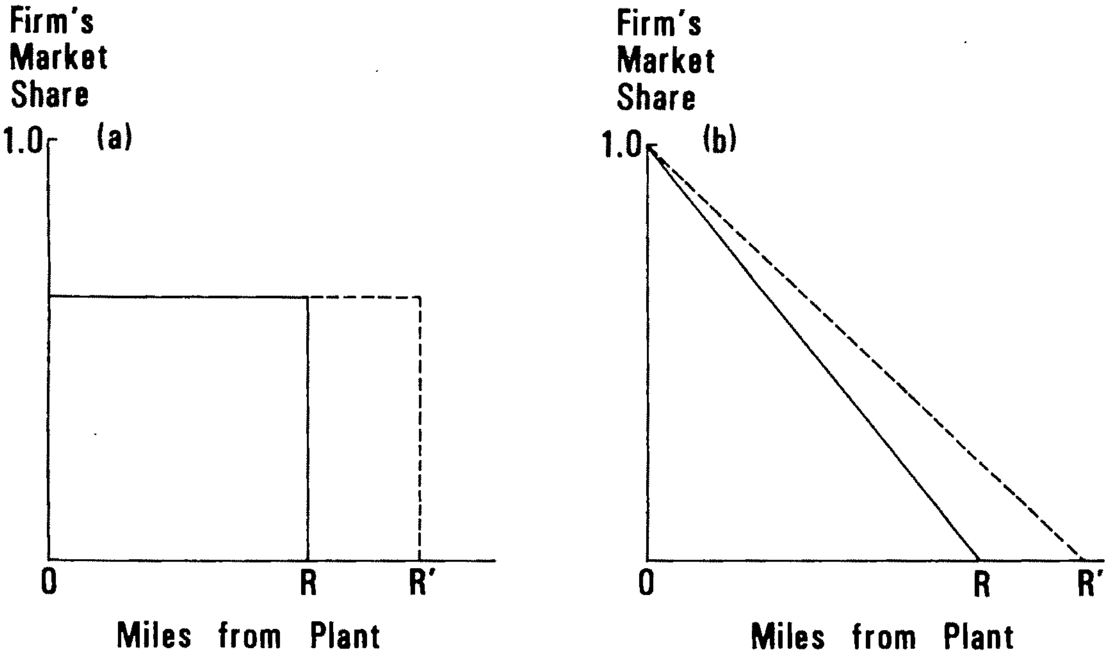

Figure 1. Comparison of uniform and decreasing market-share patterns

given demand density and uniform market-share pattern, estimates of delivery costs for a given volume and estimates of delivery-cost changes associated with volume changes. But these estimates would be based on an assumption about the market-share pattern that likely is unrealistic for most firms. Delivery-cost estimates for a given volume are based on the assumption that the firm's market share is exactly the same throughout the firm's trade area and that market share suddenly drops from this uniform level to zero at the boundary of the trade area (solid lines, figure 1a). The change in the market-share pattern assumed when volume changes is illustrated by the solid and dashed lines in figure 1a. An increase in volume from, say, Q to Q', would require an increase in the size of the trade area from, say, R to R' (equation (4)). But this implies that market share in the area from R to R' miles from the plant is increased from 0 to M, while market share in the area from 0 to R miles from the plant remains constant at M.

Model II: Linear Market-Share Pattern

In model II, the firm's market share within its trade area is assumed to be a linear function of road distance from the firm's plant. Specifically, the firm's market share at a point r road miles from the plant is given by $S = m_0 - (m_1/R)r$, where $0 \leq m_0 \leq 1$, and $m_0 - 1 \leq m_1 \leq m_0$, if $r \leq R$, and by $S = 0$ if $r > R$. The parameter m_0 represents the firm's market share at the plant location, and (m_1/R) is the rate at which market share changes with road distance from the plant. The restrictions on m_0 and m_1 prevent market share from being greater than one (100%) or less than zero within the firm's trade area.

This assumption permits a variety of market-share patterns. Market share at the plant location (m_0), may range from zero to one, and market share may increase, remain constant, or decrease with road distance from the plant. If $m_0 - 1 \leq m_1 \leq 0$, market share increases with road distance. If $m_1 = 0$, market share is constant (uniform); thus, model I is a special case of model II. If $0 \leq m_1 \leq m_0$, market share decreases with road distance. A specific decreasing market-share pattern is illustrated graphically by the solid lines in figure 1b.

The derivation of the delivery-cost function for model II parallels the derivation for model I. The quantity delivered in a trade area that extends R road miles in any direction from the plant is

$$(8) \quad Q = 4P \int_0^R \int_0^{R-x} [m_0 - (m_1/R)(x + y)]dydx = 4PR^2[m_0/2 - m_1/3],$$

and average hauling distance is

$$(9)\quad \bar{D}_{II} = (4P/Q)\int_0^R\int_0^{R-x}[m_0 - (m_1/R)(x+y)](x+y)dydx = R(4m_0 - 3m_1)/2(3m_0 - 2m_1).$$

Equation (8) may be used to eliminate R from equation (9) so that average hauling distance may be reexpressed as

$$(10)\quad \bar{D}_{II} = Q^{1/2}(4m_0 - 3m_1)/4(3m_0 - 2m_1)[P(m_0/2 - m_1/3)]^{1/2}.$$

Finally, the restricted long-run, total delivery-cost function for model II is obtained by substituting equation (10) into equation (3):

$$(11)\quad LTDC_{II} = [b_0 + B_{II}Q^{1/2} + \sum_i F_i(g_{0i} + G_{IIi}Q^{1/2})/H_i]Q,$$

where $B_{II} = b_1(4m_0 - 3m_1)/4(3m_0 - 2m_1)[P(m_0/2 - m_1/3]^{1/2}$, and $G_{IIi} = g_{1i}B_{II}/b_1$.

Equation (11) is an improvement over equation (7) because it is more general (equation (7) is a special case of equation (11), where $m_0 = M$ and $m_1 = 0$) and because it can be used to provide delivery-cost estimates for market-share patterns that likely are more typical than uniform patterns. For example, by setting $m_0 = m_1 = 1$, equation (11) may be used to estimate delivery costs for the market-share pattern shown in figure 1b. These cost estimates would be based on the assumption that market share is greatest near the plant and that it decreases with road distance from the plant until it reaches zero. Also, estimates of delivery-cost changes associated with volume changes would be based on the assumption that the firm's market share changes throughout its trade area when volume changes; that is, if volume increases from Q to Q', then the size of the trade area would increase from R to R' (equation (8)), and the market share at each point in the firm's trade area would increase as shown by comparing the solid and dashed lines in figure 1b. These assumptions seem likely to be applicable to more firms than are those underlying the uniform share pattern.

Impacts of Changes in Market-Share Patterns

Perhaps the questions of most interest to those conducting analyses of marketing firms concern the impacts of changes in the market-share assumption on cost estimates and other results of the analyses. Specifically, it may be of interest to know how changes in the market-share assumption (e.g., from a uniform to a decreasing share pattern) affect estimates obtained for delivery costs, delivery equipment requirements, trade area size, firm costs, and the least-average-cost firm size.

Delivery Operation

First, consider the impact of changes in the market-share pattern on delivery costs. The market-share pattern affects delivery costs through its impact on the average hauling distance required for any given volume; that is, if the average hauling distance for a given volume is the same for two different market-share patterns, then the delivery cost for a given volume is the same for the two patterns. Thus, the qualitative impact of changes in the market-share pattern on delivery costs for a given volume is known if the impact of changes in the market-share pattern on average hauling distance for a given volume is known.

A convenient way to compare average hauling distances for any of the market-share patterns consistent with models I or II is to calculate and compare values of a market-share index. The index may be defined such that the index value for a uniform pattern is simply the uniform share, and the index value for a nonuniform pattern is the uniform share that results in the same average hauling distance as the nonuniform pattern. The market-share index value ($\hat{M}$) for any market-share pattern consistent with models I or II is given by

$$(12)\quad \hat{M} = 0.5926(3m_0 - 2m_1)^3/(4m_0 - 3m_1)^2.$$

This expression was obtained by equating equations (6) and (10), solving for M, and denoting the solution value $\hat{M}$. The higher the index value for a market-share pattern, the lower is the average hauling distance for a given volume.

This market-share index leads to a convenient way to specify delivery-cost functions for alternative market-share patterns. The market-share index is in effect the uniform market share that is equivalent to any uniform or nonuniform market-share pattern consistent with models I or II. For example, the market-share index for the decreasing share pattern depicted in figure 1b (model II with $m_0 = m_1 = 1$) is, from equation (12), $\hat{M} = 0.5926$. Therefore, this decreasing share pattern is

equivalent to the uniform share pattern where $M = 0.5926$, and the delivery-cost function for this market-share pattern may be obtained by setting $M = 0.5926$ in equation (7). In general, the delivery-cost function for a market-share pattern with index $\hat{M}$ is given by

$$(13) \quad LTDC = [b_0 + BQ^{1/2} + \sum_i F_i(g_{0i} + G_iQ^{1/2})/H_i]Q,$$

where $B = (0.4714)b_1(P\hat{M})^{-1/2}$, and $G_i = g_{1i}B/b_1$.

Equation (13) may be used to show the qualitative impacts of changes in the market-share pattern on delivery costs for a given volume. Changes in the market-share pattern that do not change the market-share index do not change the delivery cost for a given volume, e.g., a change from a uniform market-share pattern with $M = 0.5926$ to a decreasing share pattern where $m_0 = m_1 = 1$ does not change the delivery-cost function. Changes in the market-share pattern that increase (decrease) the market-share index reduce (increase) delivery costs for a given volume, i.e.,

$$(14) \quad \partial(LTDC)/\partial\hat{M} = -BQ^{3/2}/2\hat{M} - \sum_i F_iG_iQ^{3/2}/2\hat{M}H_i < 0.$$

The qualitative impacts of changes in the market-share pattern on delivery equipment requirements for a given volume also may be determined by using the market-share index. The number of units of the ith type of delivery equipment (N_i) required for an annual volume (Q) is

$$(15) \quad N_i = (g_{0i} + G_iQ^{1/2})Q/H_i.$$

A change in the market-share pattern that increases (decreases) the market-share index will reduce (increase) the number of units required for a given volume because

$$(16) \quad \partial N_i/\partial\hat{M} = -G^{3/2}/2\hat{M}H_i < 0.$$

Different market-share patterns that have the same index will have the same delivery equipment requirements for a given volume.

The market-share index, however, may not be used to determine the impacts of changes in the market-share pattern on the distance from the plant to the boundary of the trade area (R). For any given volume (Q), R depends on the specific market-share pattern

$$(17) \quad R = (1.2247)Q^{1/2}/[P(3m_0 - 2m_1)]^{1/2}.$$

An increase in the intercept (m_0), or a decrease in the slope (m_1), of the market-share pattern reduces R for a given volume:

$$(18) \quad \partial R/\partial m_0 = -3R/2(3m_0 - 2m_1) < 0,$$

and

$$(19) \quad \partial R/\partial m_1 = 2R/(3m_0 - 2m_1) > 0.$$

R will not in general be the same for different market-share patterns that have the same index.

Least-Average-Cost Firm Size

To analyze the impacts of changes in the market-share pattern on the least-average-cost firm size, an assumption must be introduced about plant costs. Assume that given the number of hours available per season total plant costs (TPC) depend on hourly plant capacity and average volume per hour during the season:

$$(20) \quad TPC = Z_1 + Z_2qH_p, \; q \leq k,$$

where $Z = Z_1(k, H_p)$, $k = k(K, H_p)$, k is maximum hourly output that can be achieved with good management and usual operating conditions, K is rated or design capacity per hour for the plant facility, H_p is number of hours available per season for operation of plant facility, $Z_2 = Z_2(k, H_p)$, and q is average volume per hour during the season. The first term on the right-hand side of equation (20) is fixed plant costs, and the second term is variable plant costs.

To obtain a long-run plant-cost function from equation (20), it is assumed that $\partial(TPC)/\partial K = \partial Z_1/\partial K + (\partial Z_2/\partial K)qH_p > 0$. Given this assumption, the cost of producing any volume Q ($= qH_p$) is minimized if plant capacity (K), and maximum hourly output, $k = k(K, H_p)$, is as small as possible, i.e., if $k = q$. The long-run plant-cost function ($LTPC$) is as small as possible, i.e., if $k = q$. The long-run plant-cost function ($LTPC$) is therefore obtained from equation (20) by setting $q = k$ so that $k = Q/H_p$:

$$(21) \quad LTPC = Z_1(Q/H_p, H_p) + [Z_2(Q/H_p, H_p)]Q.$$

To obtain the long-run, average combined-cost function ($LACC$), sum equations (13) and (21) and divide by Q:

$$(22) \quad LACC = Z_1(Q/H_p, H_p)/Q + Z_2(Q/H_p, H_p) + b_0 + BQ^{1/2} + \sum_i F_i(g_{0i} + G_iQ^{1/2})/H_i.$$

The impact of a change in the market-share pattern on $LACC$ for a given Q is

$$(23)\quad \partial(LACC)/\partial\hat{M} = -B_1Q^{\frac{1}{2}}/2\hat{M} - \sum_i F_iG_iQ^{\frac{1}{2}}/2\hat{M}H_i < 0.$$

If there exists a unique annual volume Q^* that minimizes long-run average combined costs, the design capacity per hour of the corresponding plant facility (i.e., the least-average-cost firm size) is obtained by setting

$$(24)\quad \partial(LACC)/\partial K = [\partial(LACC)/\partial Q][\partial Q/\partial k][\partial k/\partial K] = 0$$

and solving for K^* provided that the second-order condition is met. The annual volume Q^* is obtained by using $k^* = k(K^*, H_p)$ and $Q^* = k^*H_p$. To obtain N^*_i and $LACC^*$, substitute Q^* into equations (15) and (22), respectively. These characteristics of the least-average-cost firm (i.e., K^*, k^*, Q^*, N^*_i, and $LACC^*$) depend on the market-share index but not on the specific market-share pattern. The distance from the plant to the boundary of the least-average-cost firm R^*, however, does depend on the specific market-share pattern. Given Q^* and the specific market-share pattern (i.e., values for m_0 and m_1), R^* may be obtained from equation (17).

The qualitative impacts of changes in the market-share pattern on K^*, k^*, Q^*, $LACC^*$, N^*_i, and R^* may be determined from comparative static derivatives. By substituting K^*, k^*, and Q^* into equation (24), the identity $L = [\partial(LACC)/\partial Q^*][\partial Q/\partial k^*][\partial k/\partial K^*] = 0$ is obtained. The comparative static derivatives and their expected signs are

$$(25)\quad \partial K^*/\partial\hat{M} = (-\partial L/\partial\hat{M})/(\partial L/\partial K^*) > 0,$$

$$(26)\quad \partial k^*/\partial\hat{M} = (\partial k^*/\partial K^*)(\partial K^*/\partial\hat{M}) > 0,$$

$$(27)\quad \partial Q^*/\partial\hat{M} = (\partial Q^*/\partial k^*)(\partial k^*/\partial\hat{M}) > 0,$$

$$(28)\quad dN^*_i/d\hat{M} = (\partial N^*_i/\partial Q^*)(\partial Q^*/\partial\hat{M}) + \partial N^*_i/\partial\hat{M} \gtreqless 0,$$

$$(29)\quad d(LACC^*)/d\hat{M} = [\partial(LACC^*)/\partial Q^*][\partial Q^*/\partial\hat{M}] + \partial(LACC^*)/\partial\hat{M} < 0,$$

$$(30)\quad dR^*/dm_{0|dm_1=0} = (\partial R^*/\partial Q^*)(\partial Q^*/\partial\hat{M})(\partial\hat{M}/\partial m_0) + \partial R^*/\partial m_0 \gtreqless 0,$$

and

$$(31)\quad dR^*/dm_{1|dm_0=0} = (\partial R^*/\partial Q^*)(\partial Q^*/\partial\hat{M})(\partial\hat{M}/\partial m_1) + \partial R^*/\partial m_1 \gtreqless 0.$$

Expressions (25) through (27) show that a change in the market-share pattern that increases the market-share index, *ceteris paribus*, increases the design capacity and the normal operating capacity of the least-average-cost firm and increases the least-average-cost annual volume. An increase in the market-share index may either increase or decrease the stock of delivery equipment (expression (28)) but is expected to reduce the combined average cost associated with the least-average-cost firm (expression (29)). Expressions (30) and (31) show that changes in the intercept or the slope of the market-share pattern may either increase or decrease the size of the trade area served by the least-average-cost firm.

Implications for Marketing-Firm Analysis

These results concerning the specification of delivery-cost functions for the alternative market-share patterns and the impacts of changes in the market-share patterns should improve the accuracy and usefulness of results obtained from marketing firm analyses. The accuracy of the results will be improved if attempts are made to measure actual market-share patterns and to incorporate these patterns into the specification of delivery-cost functions by using equations (12) and (13). The more nearly accurate are the assumptions used about market share in specifying cost functions, the more nearly accurate are the cost estimates for given levels of volume, estimates of cost changes associated with given changes in volume, estimates of delivery equipment requirements, and estimates of the least-average-cost firm size.

Results should also be more useful because they can be used to address questions about how firms should attempt to achieve volume changes. A common conclusion of studies of spatially located marketing firms is that typical firms can reduce costs by expanding volumes to existing capacity levels and can further reduce costs by expanding capacities and volumes to least-average-cost levels. The stated or implied recommendation is that at least some firms should increase their volumes, which in turn implies that market share within existing trade areas should be increased, that trade areas should be expanded, or both. But the results of studies have not provided estimates of how cost savings are affected by the

way in which increased volume is achieved. These estimates, which can be obtained by using the procedures just discussed, may be quite useful to firms. For example, a firm facing a decreasing share pattern may wish to know how savings are affected if volume is increased by maintaining the decreasing share pattern as compared with achieving a market-share pattern with a higher index. The cost of achieving and maintaining the higher market-share index, which may be an increasing function of the market-share index, may then be compared with the additional cost savings.[2]

This last point raises a question concerning least-cost location patterns. Least-cost location patterns have been derived given the assumption that market-share patterns are uniform (Williamson). But it may be that, for many spatially located firms, market-share patterns decrease with distance from the plant because costs of achieving and maintaining higher (e.g., 100% uniform) market-share patterns exceed the delivery-cost savings that result. Then the derivation of a least-cost location pattern would need to be based on the assumption that firms have decreasing market-share patterns. A cursory analysis suggests that if firms have decreasing market-share patterns it is not possible to derive a space-filling location pattern whereby each firm achieves the least-average-cost annual volume and trade area size.

An Empirical Application

A study of costs of retailing anhydrous ammonia fertilizer in north central Iowa illustrates the use of the procedures suggested here for measuring marketing firm costs and provides some quantitative estimates of impacts of changes in the market-share pattern on anhydrous ammonia delivery and combined retailing costs and on characteristics of the least-average-cost firm and trade area. In the study, long-run average plant costs are estimated for six levels of annual volume. Three market-share patterns are specified, and, for each market-share pattern, long-run average delivery and combined costs, delivery equipment requirements, and trade area size are estimated for each of the six levels of annual volume.

Estimates of long-run average plant costs are obtained from cost estimates for six model retail plants. Seasonal capacities for the model plants range from 450 to 3,200 tons (first row, table 1). Following the procedure used to derive equation (21), long-run average plant cost estimates (second row, table 1) are obtained by calculating the average total plant cost at the seasonal capacity for each model plant. The estimates include costs of owning and operating plant facilities, which typically include a storage vessel, a pumping system to transfer the product from rail cars or truck transports to the storage vessel and from the storage vessel to nurse tanks, a scale, and an office building, and administrative and management costs and costs of advertising and of providing services to customers.

Three alternative market-share patterns are specified. One of these, the decreasing share pattern (model II with $m_0 = m_1 = 1$), is suggested by results of a preliminary study of five anhydrous ammonia retailing operations in north central Iowa. In this study, the market share of each firm in each one-mile increment surrounding its plant is estimated by using the following procedure:[3] (*a*) the firm's 1971 sales records are used to determine the number of tons the firm sold in each one-mile increment, (*b*) the total number of tons sold in each increment by the firm and its competitors is estimated, and (*c*) for each increment, the number of tons the firm sold is divided by the estimated total tons that all firms sold to arrive at an estimate of the firm's market share for the increment. The general characteristics of the estimated market-share patterns for the five firms suggest a decreasing share pattern. Market share is 100% near the plant location; it decreases with road distance from the plant location, and firms with greater annual volumes have larger trade areas; i.e., market share remains positive for these firms in more distant one-mile increments. The two other market-share patterns, a uniform 100% pattern and a uniform 33% pattern, are chosen arbitrarily.

Estimates of long-run average delivery costs, delivery equipment requirements, and trade areas are obtained by using equations (12) and (13), (15), and (17), respectively. The market-share index values obtained from equa-

[2] Costs associated with gaining and maintaining a market-share pattern that has a higher index might include, for example, increased advertising and customer service costs or price reduction.

[3] The first one-mile increment includes the area from zero to one road miles in any direction from the plant, the second one-mile increment includes the area from one to two road miles in any direction from the plant, etc.

Table 1. Estimated Long-Run Average Costs, Delivery Equipment Stocks, and Market Area Size for Three Market-Share Patterns

	Model Firm					
Item	1	2	3	4	5	6
Annual volume (tons)	450	675	900	1,800	2,300	3,200
Plant cost per ton	$ 7.74	$ 7.05	$ 6.68	$ 6.00	$ 5.80	$ 5.54
100% uniform share pattern						
Delivery cost per ton	$11.41	$11.74	$11.60	$12.04	$12.15	$12.52
Combined cost per ton	$19.16	$18.79	$18.29	$18.04	$17.96[a]	$18.06
Number of pickup trucks	1	2	2	5	6	9
Number of nurse tanks	8	12	16	32	41	58
Number of applicators	6	9	12	24	31	44
Distance from plant to boundary of trade area (miles)	4.0	5.0	5.7	8.1	9.1	10.8
Decreasing market-share pattern						
Delivery cost per ton	$11.55	$11.91	$11.80	$12.55	$12.78	$13.03
Combined cost per ton	$19.29	$18.95	$18.48[a]	$18.55	$18.58	$18.57
Number of pickup trucks	1	2	2	5	7	10
Number of nurse tanks	8	12	16	33	42	59
Number of applicators	6	9	12	25	32	44
Distance from plant to boundary of trade area (miles)	7.0	8.6	9.9	14.0	15.8	18.7
33% uniform share pattern						
Delivery cost per ton	$11.75	$12.15	$12.89	$13.20	$13.43	$14.07
Combined cost per ton	$19.49	$19.20[a]	$19.57	$19.20	$19.23	$19.60
Number of pickup trucks	1	2	3	6	8	12
Number of nurse tanks	8	12	17	34	43	62
Number of applicators	6	9	13	25	32	46
Distance from plant to boundary of trade area (miles)	7.0	8.6	9.9	14.0	15.8	18.7

[a] Minimum average combined cost for market-share pattern. For the uniform 33% market-share pattern, combined average costs are a fraction of a cent lower for firm 2 than for firm 4.

tion (12) are 0.5926 for the decreasing share pattern, 1.0 for the 100% uniform pattern, and 0.333 for the 33% uniform pattern. Three types of delivery equipment are used in anhydrous ammonia retailing: nurse tanks to transport the product from the plant to farms; pickup trucks to tow nurse tanks; and applicators to inject the product into the soil. It is assumed that delivery equipment could be added only in discrete units, so the number of units of each type of delivery equipment required for a given annual volume is calculated and then rounded up to the nearest integer value before the delivery-cost estimate is calculated. The lower portion of table 1 shows long-run average delivery costs, long-run average combined costs, the stock of delivery equipment, and the size of trade area required for the capacity annual volume of each model firm for each market-share pattern.

Each column in table 1 shows, for a given annual volume, the impacts of changes in the market-share pattern on delivery and combined costs, on delivery equipment requirements, and on the size of the trade area. Delivery and combined costs are lower and the number of units of delivery equipment required is the same or lower for patterns with higher index values.[4] An increase in the intercept of the market-share pattern with the slope held constant (e.g., a change from a uniform 33% to a uniform 100% pattern) or a decrease in the slope of the market-share pattern with the intercept held constant (e.g., a change from a decreasing market-share pattern to a uniform 100% pattern) reduces the size of the trade area needed for a given annual volume. These impacts are consistent with the signs of the partial derivatives in expressions (14), (16), (18), and (19).

The results in table 1 also are consistent with expressions (27) and (29): the least-average-cost annual volume increases and the minimum average combined-cost decreases as

[4] An increase in the market-share index decreases the delivery equipment time required, but because the last fraction of a delivery unit required is rounded up to a full unit, the number of units required may not decrease.

the market-share index increases. Delivery equipment stocks of the least-average-cost firm increase with the market-share index, which suggests a positive sign for the comparative static derivative in expression (28). Also, the results show that an increase in the intercept or the slope of the market-share pattern increases the distance from the plant to the boundary of the trade area of the least-average-cost firm, which implies positive signs for the comparative static derivatives in expressions (30) and (31).

The results show that changes in the market-share pattern have a substantial impact on the least-average-cost capacity of an anhydrous ammonia retailing firm but only a small impact on combined average costs. The plant capacity and delivery equipment stock of the least-average-cost firm for the decreasing share pattern are less than half of those for the uniform 100% market-share pattern. Combined average costs of the least-average-cost firm are estimated to be less than 3% higher for the decreasing than for the uniform 100% market-share pattern.

These and some other results of the study are used to offer recommendations about cost-reducing adjustments for a typical retailer. Average annual volume for a typical retailer was 521 tons, and survey information indicates that the typical retailer had ten applicators, fifteen nurse tanks, and one pickup. It is estimated that a typical retailer could reduce costs by \$3.36 per ton, or by 15%, by reducing his stock of delivery equipment to the level required by the more efficient retailers surveyed. The typical retailer could realize further, but less substantial cost savings (from \$19.31 to \$18.95 or \$0.36 per ton), by increasing his annual volume to the capacity level for model firm 2. If the retailer further increases his annual volume to the least-average-cost level for the decreasing share pattern, his costs would drop by only about \$0.47 per ton (from \$18.95 to \$18.48). A comparison of combined average costs for the decreasing and 100% uniform share patterns indicates that a retailer's opportunities are relatively small for further cost reductions by achieving a 100% uniform market share within his trade area. For example, if volume is increased from 900 to 2,300 tons by converting a decreasing share pattern to a 100% uniform pattern, costs would only be reduced from \$18.48 to \$17.96 per ton, or by less than 3%. These cost savings likely would not offset the additional costs of gaining and maintaining a uniform 100% market-share pattern.[5] Estimates of cost savings available through other adjustments (e.g., expanding season length) are presented in Raikes and Heubrock.

Summary and Conclusions

A common assumption underlying the specification and estimation of cost functions for firms with assembly or delivery operations has been that the firm has a uniform market share within the trade area it serves. This assumption probably is quite unrealistic for many firms, and a more plausible assumption is that market share changes, and probably decreases, with distance from the plant. The approach suggested here is to measure market-share patterns of representative firms, to approximate actual patterns with linear patterns, and to incorporate the appropriate linear pattern into the specification of the delivery-cost function. A procedure for specifying delivery-cost functions for alternative linear market-share patterns was developed. Expressions that show qualitative impacts of changes in market-share patterns on costs and related results were derived, and some quantitative estimates were presented of impacts of changes in market-share patterns on costs and related results for anhydrous ammonia retailing firms.

Some limitations and possible extensions of the study should be noted. The specification of the delivery-cost function is based on assumptions that there is a square grid road system and that delivery technology is not a function of volume. These assumptions fit anhydrous ammonia retailing in north central Iowa, but the cost function would have to be respecified to fit situations in which these assumptions are not appropriate. The procedures presented here permit incorporation of only linear market-share patterns into the specification of delivery-cost functions. Incorporation of nonlinear patterns would require different procedures. No conclusions about typical market-share patterns are possible. All that can be said is that market-share patterns for a small sample of anhydrous

[5] On the other hand, if additional costs of gaining and maintaining a uniform 100% market-share pattern are negligible, then a 3% reduction in combined average costs likely would result in a substantially larger percentage increase in profits.

ammonia retailers in north central Iowa were roughly consistent with the decreasing share pattern. The hypothesis that costs of gaining and maintaining market-share patterns with higher indexes exceed cost savings was suggested but not tested. Finally, no effort was made to determine efficient location patterns given that market share is a function of distance from the plant.

The approach suggested here does offer some advantages. Because it is possible to incorporate several alternative market-share patterns into the specification of delivery-cost functions, it should be possible to obtain more accurate estimates of delivery-cost–volume relationships. Also, the approach makes it possible to measure differences in cost savings associated with different ways of expanding volume, i.e., by changing the market-share pattern in various ways.

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Prices, Farm Outputs, and Income Projections under Alternative Assumed Demand and Supply Conditions

Chung J. Yeh

A two-equation aggregate demand and supply simulation model with Koyck-type geometrically distributed lags is used to examine the impacts of alternative demand and supply shifts on aggregate farm output, prices, and income. Impacts of inflation on important farm sector indicators are also examined. Projected solutions to 1985 indicate that strong demand shifts are needed to maintain a favorable level of prices and farm incomes. Results further suggest that the U.S. farm sector is particularly sensitive to unexpected changes or shifts in demand, and supply and prolonged inflation in the general economy.

Key words: aggregate farm output, demand, income, inflation, price, projection, simulation, supply.

Since the end of World War II and especially during 1953–71, the major U.S. agricultural problem was excess farm output. Commodity supplies for most of this period grew faster than consumer demand. Consequently, large stocks were held by the federal government and commodity prices were depressed. The Commodity Credit Corporation (CCC) inventories were mostly above $3 billion, net farm income in current dollars remained around $11 to $13 billion, and government payments increased from $0.2 billion to well over $3 billion (USDA 1973, 1974a,b). An analysis of commodity supply functions, their interrelationships, and supply-control programs occupied the attention of agricultural economists during this period (Heady et al. 1961). Not until 1972 did U.S. agriculture experience high farm prices and net farm income. This condition continued through most of 1973–75 because of food shortages in some developing countries, a sudden increase in demand by nations in the communist block, and the depletion of formerly burdensome surplus CCC stocks. Accompanying this emerging benchmark, which Brandow (1974) regards as high demand for U.S. agricultural products by foreign countries and Hathaway considers the end of overcapacity, was a move toward a more market-oriented U.S. agriculture.

For the future, the questions often asked are whether we are in a period of a temporary bulge in the demand for U.S. farm output and will return to the tendency of overproduction or have we entered a new epoch in which it will be difficult for supply to keep pace with demand? This basic uncertainty translates into concern about farm prices and income and U.S. agriculture's ability to play an increasingly greater role in the world food situation. These problems can be examined in the context of aggregate U.S. farm output supply and demand.

The purpose of this article is to analyze and evaluate this uncertain agricultural future and in particular the possible adjustments in farm prices, output, income, and cost of production. Alternative demand and supply scenarios are employed to reflect different possible market conditions. In addition, impacts of inflation on important farm sector indicators are also examined.

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The Model

A simulation model is built around a simultaneous formulation of aggregate supply and demand equations for U.S. agriculture.[1] A Koyck-type distributed lag model is assumed in which both quantities demanded and supplied are functions of current and lagged prices. Furthermore, both demand and supply functions can shift at different rates from year to year. The original distributed lag forms are the aggregate demand function,

$$(1)\quad Q_{d,t} = \alpha_d PR_t^{\lambda^0\beta_d}\, PR_{t-1}^{\lambda^1\beta_d} \ldots PR_{t-\infty}^{\lambda^\infty\beta_d}\, e^{\sum_{i=t_0}^{t} g_{d,i}},$$

and the aggregate supply function,

$$(2)\quad Q_{s,t} = \alpha_s \left(\frac{PR}{PDFE}\right)_t^{\mu^0\beta_s}\left(\frac{PR}{PDFE}\right)_{t-1}^{\mu^1\beta_s} \ldots \left(\frac{PR}{PDFE}\right)_{t-\infty}^{\mu^\infty\beta_s} e^{\sum_{i=t_0}^{t} g_{s,i}},$$

where Q_d and Q_s are quantities demanded and supplied, respectively, and PR is prices received by farmers (endogenous variables); $g_{d,i}$ and $g_{s,i}$ are rates of shift in demand and supply in the ith year, respectively, $t_0 \leq i \leq t$, and $PDFE$ is prices paid by farmers for farm operating expenses (exogenous variables); β_d and β_s are short-run price elasticities of demand and supply, respectively; λ and μ are weights placed on PR_{t-1} and $(PR/PDFE)_{t-1}$; α_d and α_s are constant terms in least squares demand and supply equations, respectively; t is the index year; and t_0 is the base year.

Quance and Tweeten built a similar simulation model around a recursive formulation. The present model differs considerably from their formulation. First, their recursive model assumes constant year-to-year shifts in demand and supply. Historically, demand and supply have not shifted at constant rates, nor is demand and supply likely to shift at fixed rates in the future.[2] The present model assumes that the ith year shifts in demand and supply are $e^{g_{d,i}}$ and $e^{g_{s,i}}$. The cumulated shifts from the base year are $e^{\sum_{i=t_0}^{t} g_{d,i}}$ and $e^{\sum_{i=t_0}^{t} g_{s,i}}$ for demand and supply, respectively (equations (1) and (2)). This assumption provides the model with the capacity to examine historical trends and the flexibility to simulate the impacts of differing future year-to-year shifts in demand and supply.

Second, the model differs from Quance and Tweeten's formulation in that the quantity supplied reacts within one year to a change in market prices and all other geometrically weighted past prices. Current prices were included in the lagged supply function because estimates indicated that about 40% of cash receipts by farmers are from commodities whose supply can be reasonably considered a function of current prices (USDA 1974b). Furthermore, the data base and the data generated under the present model are annual averages. Clearly, through the averaging process current prices received contains about one-half of the first-year lag effects.

Finally, in the recursive formulation the cobweb effect begins to accumulate in a few years and the prices received index and equilibrium output fluctuate wildly from year to year. This unreasonable year-to-year variation is eliminated by using current prices in the lagged supply function.

The reduced equations of the distributed lag models are the aggregate demand function,

$$(3)\quad Q_{d,t} = \hat{\alpha}_d PR_t^{\beta_d}\, Q_{d,t-1}^{(1-\delta_d)}\, e^{\delta_d \sum_{i=t_0}^{t-1} g_{d,i} + g_{d,t}},$$

and the aggregate supply function,

$$(4)\quad Q_{s,t} = \hat{\alpha}_s PR_t^{\beta_s}\, Q_{s,t-1}^{(1-\delta_s)}\, e^{\delta_s \sum_{i=t_0}^{t-1} g_{s,i} + g_{s,t}}\, PDFE^{-\beta_s},$$

where $\hat{\alpha}_d$ is a constant term in the reduced demand function, $\hat{\alpha}_d = \alpha_d^{(1-\lambda)}$; $\hat{\alpha}_s$ is a constant term in the reduced supply function, $\hat{\alpha}_s =$

[1] This aggregate farm output model is one component of the ERS, USDA, National Interregional Agricultural Projections (NIRAP) System (USDA 1976). The system currently comprises six models. They are aggregate farm output, commodity, price-quantity, technology, input, and the state and regional models. Most of them are operational or near operational. As a component of the NIRAP system, this model provides the overall constraints on projections of alternative futures. The model has the capacity to simulate several alternative farm policies. Also, impacts of year-to-year changes in demand, supply, and inflation can be quickly evaluated.

[2] Their model not only fails to simulate the past trend with a reasonable degree of accuracy, which is essential for any simulation model, but also has limited capacity to analyze and evaluate certain future market conditions.

$\alpha_s^{(1-\mu)}$; and δ_d and δ_s are proportions of desired or optional adjustment in demand and supply in one year, respectively, $\delta_d = (1 - \lambda)$ and $\delta_s = (1 - \mu)$.

The reduced-equation system contains two equations in three endogenous variables (PR, Q_d, Q_s). The model is completed by adding an auxiliary equation (5) representing the relationship between Q_d and Q_s:

$$(5) \qquad Q_{d,t} = Q_{s,t}\,(1 - DIAA_t).$$

Equation (5) specifies that government policy is exogenous to the model and that the government exercises its policy through the control of the diversion rate ($DIAA$), which in turn is fed into the supply function to establish a general equilibrium. Under the assumptions, government diversion policies will shift the supply curve upward to the left.

Inflation is treated as exogenous to the model and is assumed to have negative impacts on the supply curves, namely, shifting the supply curves upward to the left by the amount $PDFE_t^{-\beta_s}$.

The reduced-equation model (equations (3) and (4)) permits the projection of prices received by farmers and quantity marketed (quantity demanded at the equilibrium). By allowing the diversion rate in equation (5) to vary, alternative farm policies can be examined. In a free market such as assumed in this study, the diversion rate ($DIAA$) is assumed to be zero after 1974.

The reduced equations determine only the prices received and farm outputs under alternative demand and supply scenarios. Additionally, the index of prices paid, farm income, and production expenses are estimated using the equations discussed below.

Inflation in the farm input sector is measured by the index of prices paid by farmers, which in turn is determined by its components. Components of prices paid (USDA 1975a) are divided into four subgroups: family living (FL), interest, taxes, and wages (ITW), interfarm sales (IFS), and other production items (PI). The indexes are then computed and aggregated according to equations (6) (for the index of prices paid by farmers including FL) and (7) (for the index of prices paid by farmers excluding FL):

$$(6) \quad PD_t = PD_{t-1}\Bigg(1.0 + \Bigg(0.395FLINF_t + 0.406PIINF_t + 0.096ITWINF_t + 0.103\left(\frac{PR_{t-1}}{PR_{t-2}} - 1.0\right)\Bigg)\Bigg),$$

and

$$(7) \quad PDFE_t = PDFE_{t-1}\Bigg(1.0 + \Bigg(0.67\,PIINF_t + 0.16\,ITWINF_t + 0.17\left(\frac{PR_{t-1}}{PR_{t-2}} - 1.0\right)\Bigg)\Bigg),$$

where the coefficients are the relative weights of expense components[3] and $FLINF$, $PIINF$, $ITWINF$, and PR_{t-1}/PR_{t-2} are the rates of inflation associated with FL, PI, ITW, and IFS at the farm level, respectively.[4]

Equations (6) and (7) assume that for the period 1967–74 for each 1% increase in the implicit price deflator, prices paid by farmers for FL, ITW, and PI will increase at 1.02%, 1.91%, and 1.02%, respectively. It is further assumed that from 1975 on, the relationships will gradually be restored to the 1953–71 levels of 0.78% and 0.59% for FL and PI, respectively, and 1% for ITW. The annual rate of restoration is $1/n$, where $n = 2$ for 1975, $n = 3$ for 1976, etc.

Production expenses are a function of changes in resource prices and changes in production inputs and are assumed to have the form

$$(8) \quad PE_t = PE_{t-1}\Bigg(1.0 + \Bigg(0.67\,PIINF_t + 0.16\,ITWINF_t + 0.17\left(\frac{PR_t}{PR_{t-1}} - 1.0\right)\Bigg)\Bigg)\left(\frac{RESX_t}{RESX_{t-1}}\right),$$

where $RESX_t$ is the index of production inputs in year t.

Gros[illegible] receipts in year t are equal to the quantit[illegible]ed (QP) in year t weighted by the prices [illegible]ived index and is given by

[3] These estimates are based on the 1958 price weights used by the USDA in the construction of the agricultural price index. In 1958, an average farmer spent 39.5% of his total expenditures for FL, 9.6% for ITW, 40.6% for PI, and 10.3% for IFS. If FL is excluded from the computation, then the weights are 67% for PI, 16% for ITW, and 17% for IFS.

[4] For the period 1953–71, the farm sector appears to have experienced the same degree of inflation experienced by the general economy measure by the GNP implicit deflator. For each 1% increase in the implicit deflator, farm operating expenses increase 0.982% and farm expenses including family living increase 0.902%. Farmers were especially hard hit during the 1967–74 period and experienced 50% or more inflation than the general economy. The relationships are 1.34%, 1.63%, 1.62%, and 1.65% for FL, ITW, PI, and PE (farm operating expenses). For 1953–74 as a whole, the relationships are 1.02%, 1.91%, 1.02%, and 1.27% for FL, ITW, PI, and PE, respectively.

$$(9) \qquad GFR_t = QP_t \frac{PR_t}{PR_{67}}.$$

Gross farm income is defined as the sum of gross farm receipts and government payments (G). In a free market government payments are assumed to be zero. However, in a controlled market government payments are assumed to be equivalent to the payments for set-aside acreages under a government diversion program ($DIAA$):

$$(10) \qquad GFI_t = GFR_t + G_t.$$

Net farm income is the difference between gross farm income and production expenses:

$$(11) \qquad NFI_t = GFI_t - PE_t.$$

The Parameters

The reduced demand function equation (3) has two parameters. They are short-run demand elasticity (β_d) and the lag parameter in demand ($\delta_d = 1 - \lambda$). There are numerous statistical estimates of the elasticity of demand for food at the aggregate level. The earliest estimates ranged from a high of −0.34 by Brandow (1961) to a low of −0.24 by Waugh. A separate estimate by Girshick and Haavelmo and Bucholz, Judge, and West placed the elasticity at −0.25. The latest work by George and King produced an elasticity of −0.24. Unfortunately, none of these are farm-level estimates, nor are they short-run estimates. Theoretically, the short-run elasticity is less than in the long run, and the farm-level elasticity is less than at retail level. Tweeten estimated the short-run farm-level elasticity as −0.25 (1967, 1970), and Brandow computed the long-run farm-level elasticity at −0.23 (1961). This study uses −0.15 as the short-run farm-level demand elasticity and −0.214 as the long-run farm-level elasticity with the lag parameter in demand ($\delta_d = 0.7$). This set of elasticities seems to predict the 1967–74 historical period better than the elasticities estimated by the previous studies.

Parameters included in the reduced supply function equation (4) are short-run supply elasticity (β_s) and the lag parameter in supply ($\delta_s = 1 - \mu$). Heady and Tweeten presented three estimates of supply elasticities: (*a*) a direct least squares estimate of 0.1 in the short run and 0.6 in the long run, (*b*) a separation of the yields and basic production unit components of supply placing the short-run elasticity at 0.25 and the long run at 1.79, and (*c*) a separation of elasticities of production and elasticities of input demand resulting in a short-run elasticity of 0.256 and long-run elasticity of 1.518. A more recent estimate by Tweeten and Quance placed the short-run elasticities at 0.1 for decreasing price and 0.15 for increasing price; the long-run elasticities were 0.8 for decreasing and 1.5 for increasing price. After a considerable number of simulation runs and in particular after considering the ability to predict the 1967–74 historical period, it was decided to use 0.20 as the short-run elasticity and 1.0 for the long-run elasticity with the lag parameter in supply ($\delta_s = 0.20$).

Scenarios

In the reduced model, the exogenous variables are the shift in demand (g_d), shift in supply (g_s), and prices paid by farmers for farm operating expenses ($PDFE$). Since $PDFE$ is assumed a function of inflation (equation (7)), inflation is considered an exogenous variable in the model. The data base for these variables are divided into two periods: a historical period of 1967–74 and alternative scenarios for the period after 1974.

Increases in demand for farm outputs are measured by three variables—population, real per capita disposable income, and exports. Changes in these variables are further adjusted to the domestic and foreign shares of total demand for U.S. farm outputs.

U.S. population increased at an average of 0.97% annually from 1967 to 1974. With falling birth rates, the 1974 growth was only 0.72%. Real per capita disposable income grew at an annual average of 2.5% during the same period except in 1974, which had a negative growth of 3.4%. With assumed income elasticity for farm outputs at 0.15 and domestic demand accounting for about 85% of total demand for farm outputs, changes in demand due to increases in population and incomes was estimated at 1.18% annually for 1967–74.

Foreign demand for U.S. farm outputs declined slightly in the late 1960s. But in the early 1970s, the general upward trend accelerated and exports increased 38% in 1973, reaching an all-time high. As a result, the increase in foreign demand for U.S. farm output contributed almost 85% of the 8.51% total demand shift in 1973. The average increase in total

lemand due to the foreign demand was 1.53%. Thus, the increase in demand for U.S. farm ıutput, both domestic and foreign markets :ombined, averaged 2.71% for 1967–74.

For the period after 1974, demand shift rates .re derived from the constant-price compo-ıent of the Economic Research Service's Na-ional Interregional Agricultural Projections ;ystem (Smith). Under the baseline scenario, he demand shift is projected at 1.6%, com-ıounded annually. This assumes a series E ıopulation (a population growth rate of 0.85% o year 2000) and moderate growth in per :apita income and farm exports.[5] In addition, . low demand scenario of a 1.2% shift in de-nand and a high demand scenario of a 3% shift .re also examined in this study.

I turn next to shifts in the supply function. Since 1967, agricultural productivity in the J.S. has been growing at an average rate of % per year (USDA 1975b). The changes are nostly positive except in 1970, 1972, and 1974, vhen the changes were −0.6%, −1.1%, and -5.1%, respectively. The biggest one-year in-:rease in productivity was 8.8% in 1971.

Productivity projections are derived from he technology component of the NIRAP sys-em (Lu). The baseline productivity growth is :stimated at 1.14% per year compounded for he period 1975–84. The baseline assumes a % annual increase in research and education :xpenditures (R&E). A more ambitious "high echnology" assumption is a 7% increase in R&E annually plus three unprecedented ıreakthroughs in technology.[6] Under this as-umption, productivity growth is projected at .21% per year. However, 1.21% is a conser-'ative estimate of the potential upper bound ın productivity growth. To provide a wider :stimate for the high production scenario, this tudy uses 2%.

In this study, inflation is measured by the ;ross national product implicit price deflator. The rates fluctuated mostly around 3% to 6% ıetween 1967 and 1974 with an average of '.2% for the whole period (Council of Eco-ıomic Advisors). The 3.2% rate increase in 1967 was the lowest for this period, while the 10.2% increase in 1974 was the highest. By excluding the double-digit figure in 1974, the annual average drops from 5.2% to 4.4%.

Inflation appears to have slowed down considerably in 1975 from the 1974 level. However, it is still high, and it is reasonable to assume that such a high rate will not prevail in the long run. Thus, in this study, we assume that in the long run an average of 4% annual rate of inflation will continue. In addition, a rate of inflation of zero and its impacts are also examined.

As discussed above, for the period 1975–85, three rates of shift in demand—1.2%, 1.6%, and 3%, two rates of shift in supply—1.14% and 2%, and two rates of inflation—0 and 4%—are considered. The scenarios formulated from the alternative combinations of these rates are summarized in table 1.

The Results

Simulating the Period 1967–74

Actual shifts in demand and supply and rates of inflation are used in simulating the period 1967–74. In this simulation, the index of prices received is [illegible]erestimated while the projected equilibrium output is slightly underestimated (table 2). Most of the errors associated with

Table 1. Alternative Demand, Supply, and Inflation Scenarios, 1975–85

Scenario[a]	Shift in Demand	Shift in Supply	Rates in Inflation
	%	%	%
Low dem[illegible]			
I	1.2	1.14	0
II	1.2	1.14	4
III	1.2	2.00	0
IV	1.2	2.00	4
Moderate demand			
V	1.6	1.14	0
VI	1.6	1.14	4
VII	1.6	2.00	0
VIII	1.6	2.00	4
High demand			
IX	3.0	1.14	0
X	3.0	1.14	4
XI	3.0	2.00	0
XII	3.0	2.00	4

[a] The basic set of parameters associated with these scenarios are demand elasticities of −0.15 in the short run and −0.214 in the long run and supply elasticities of 0.20 in the short run and 1.0 in the long run.

[5] The moderate income growth with series E population as-umes a 3% annual growth rate for per capita disposable personal ıcome from 1973 to the year 2000. The moderate export level ses the conservative assumption of continued growth in import emand by foreign countries constrained by high prices and poli-ies of major importing countries to attain self-sufficiency and the ventual resulting in a return to trends established prior to 1972 for ereals.

[6] The three unprecedented breakthroughs in technologies are vinning in beef cattle, bioregulators, and photosynthesis en-ancement.

Table 2. Actual and Simulated Values of Select Variables, United States, 1967–74

	Prices Received		Prices Paid		Price Ratio		Equilibrium Output		Realized Gross Farm Receipts		Production Expenses		Net Farm Income	
Year	Actual	Simulated	Actual	Simulated	Actual	Simulated	Actual	Simulated	Actual	Simulated	Actual	Simulated	Actual	Simulated
1967	254	254	342	342	74	74	47	47	47	47	38	37	12	12
1968	261	280	355	354	74	78	47	47	48	52	39	39	12	16
1969	275	305	373	375	74	81	49	46	53	55	42	41	14	18
1970	280	352	390	399	72	88	50	47	55	65	44	45	14	23
1971	284	269	410	423	69	64	51	49	74	52	47	44	13	12
1972	320	359	432	427	74	84	52	49	66	69	52	47	18	26
1973	438	398	496	465	88	85	55	52	94	81	64	53	32	30
1974	465	498	576	518	81	96	55	52	101	101	75	64	27	37

Sources: Actual figures are estimated from USDA 1973, 1974a,c.
Note: The 1974 values are preliminary estimates.

the projected index of prices received were off by 10% except for the year 1970, which was overestimated by 26%. The errors associated with projected equilibrium outputs were mostly less than or near 6%. Four sources are basically responsible for these errors. First, the exact magnitudes of the parameters may be incorrect. Second, the initial conditions, especially the estimated quantity marketed and the supply shifts, are based on U.S. Department of Agriculture estimates. Although these data are adjusted to fit the definitions in this study, some statistical discrepancies and terminology problems exist. Third, assumptions concerning the impact of inflation at the farm level (equations (6) and (7)) might have overestimated the upward shift in the supply curve. Consequently, the prices received would have been overestimated and the quantity marketed would have been underestimated. Finally, there are also some random errors associated with the simulation.

The simulated prices paid were generally higher than the actual values, but most were within a 6% range. Of all the variables projected, net farm income seems to fluctuate the most violently, especially for the years 1970, 1972, and 1974, since net farm income has a relatively smaller value. Further, the errors associated with the net farm income estimates come from two sources—realized gross farm income and production expenses. Consequently, the compound errors on net farm income are magnified considerably.

To test the goodness of fit of the model, the following equation is used:

$$S = a + bA, \tag{12}$$

where S is simulated results, and A is actual values. Equation (12) is used merely to test the goodness of fit of the simulated values. A perfect fit of the model for the historical period would result in $a = 0$, $b = 1$, and $r^2 = 1$. Results indicate that all intercepts are 0 at the 1% level. However, at the 5% level, the prices paid and the production expenses are all significantly different from 0 (table 3). The b values are all equal to 1 except the prices paid at the 5% level and the production expenses at the 1% level. All projected values seem to be within reasonable enough ranges of the actual values to justify using the model for long-run analysis.

The Most Realistic Scenario for 1975–85

Perhaps the most realistic scenario is scenario VI—a 1.6% shift in demand, a 1.14% shift in

Table 3. Regression Coefficients and *t*-values between the Simulated Values and the Actual Estimates, 1967–74

Items	Prices Received	Prices Paid	Equilibrium Quantity	Gross Farm Receipts	Production Expenses	Net Farm Income
$\hat{a}$	7.23	−124.17	−9.91	2.62	−18.08	1.97
t-value for H_0: $a = 0$	0.12[a]	−2.97	−0.94	0.17	−3.50	0.46
$\hat{b}$	0.93	1.32	1.25	0.99	1.47	0.73
t-value for H_0: $b = 1$	0.42	3.21	1.15	0.05	4.32	1.50
R^2	0.83	0.97	0.85	0.75	0.97	0.72

[a] The critical t-values at six degrees of freedom are $t = 2.447$ for $\alpha = 0.05$ and $t = 3.707$ for $\alpha = 0.01$.

Table 4. Equilibrium Solutions under Scenario VI, 1974–85

Year	Prices Received	Prices Paid	Equilibrium Quantity	Production Expenses	Net Farm Income: Current	Net Farm Income: Real[a]
	1910–14 = 100		——— Billion $ ———			
1974 actual	465	576	55.1	74.8	27.2	27.2
1974	498	518	51.5	64.2	37.7	37.7
1975	435	549	52.7	63.6	26.9	25.8
1976	463	559	53.2	66.0	31.0	28.7
1977	479	579	53.7	68.0	33.2	29.5
1978	493	597	54.2	70.1	35.2	30.1
1979	508	616	54.7	72.1	37.3	30.7
1980	523	635	55.3	74.2	39.5	31.2
1981	538	655	55.8	76.4	41.8	31.7
1982	553	675	56.4	78.6	44.1	32.2
1983	568	696	57.0	80.9	46.5	32.7
1984	584	717	57.5	83.2	49.0	33.1
1985	601	738	58.1	85.6	51.9	33.7

[a] In 1974 dollars.

supply, and a 4% rate of inflation (table 4). Under this scenario, the prices received index increases 21% between 1974 and 1985. On the basis of 1910–14 prices, the index increases from 497 in 1974 to 601 in 1985. The equilibrium output increases 13%, from $51.5 billion in 1974 to $58.1 billion in 1985. The most critical problem is the sudden drop in prices received index and net farm income in 1975. This is due to the fact that between 1967 and 1974 demand shifts are relatively high, especially the 3.96% shift in demand in 1974, although the supply shift was estimated at −5.1% in 1974. Adjusting to normal weather conditions, supply shift is estimated to be 4% in 1975. Therefore, a sudden drop in demand in 1975 to 1.6% and a sudden increase in supply to 4% reduce the prices received index by more than sixty points, which in turn reduces net farm income (both in current and real) by around $11 billion. Although net farm income in current dollars begins to move above the 1974 level in 1980, real net farm income does not move above the simulated 1974 level by 1985. If inflation persists at an annual rate of 4%, by 1985 net farm income in 1974 dollars will decrease $5 billion, from $37.6 billion to $33.7 billion, while net farm income in current dollars increases more than $14 billion, from $37.6 billion to $51.9 billion.

Another problem is farmers' inability to pass increased costs to consumers. Between 1974 and 1985, production expenses are projected to increase 33%, prices received by farmers only 21%. However, under the 4% inflation rate assumption the inflation index increases 54% during the same period. Productivity growth more than compensates for the differences between the prices received index and the compounded inflation index according to the baseline scenario. The result is a relatively higher net farm income.

Alternative Scenarios, 1975–85

Four scenarios (V–VIII) are considered under the moderate shift in demand (table 5). Number VI, the baseline or most likely, has been discussed fully in the previous section. If the supply curve shifts at an annual rate of 2% instead of 1.14%, while shifts in demand and inflation are maintained at 1.6% and 4% annually, respectively (from scenarios VI to VIII), equilibrium output increases an additional 2% in 1985, equivalent to $1.1 billion. The prices recei[illegible]ex declined forty-eight points, from 6[illegible]3 (1910–14 = 100). Net farm income [illegible]rent dollars dropped almost $3 billion. The assumption of an almost 1% additional shift in supply is probably too high. However, there is an estimated 96 million acres of noncropland with high potential for conversion to cropland use, and there are some unprecedented technologies that could come off the shelf to boost agricultural productivity.

If the annual rate of inflation is reduced to zero while the supply shift is maintained at 1.14% (scenario V), the prices received index in 1985 drops more than 5% from the 1974 simulated level. But because of a 19% increase in equilibrium output, from $51.5 billion in

Table 5. Equilibrium Solutions under Alternative Scenarios, 1985

Scenarios	Prices Received (1910–14 = 100)	Prices Paid (1910–14 = 100)	Equilibrium Quantity	Production Expenses	Net Farm Income: Current	Net Farm Income: Real[a]
			Billion $			
1974 actual	465	576	55.1	74.8	27.2	27.2
1974 projected	497	518	51.5	64.3	37.6	37.6
Low demand						
I	446	526	59.1	62.0	41.8	41.8
II	570	734	56.2	82.1	44.0	28.6
III	410	521	60.2	57.7	39.7	39.7
IV	524	727	57.3	76.4	41.8	27.2
Moderate demand						
V	471	529	61.1	64.8	48.5	48.5
VI	601	738	58.1	85.6	51.9	33.7
VII	433	523	62.3	60.2	46.0	46.0
VIII	553	731	59.2	79.7	49.2	32.0
High demand						
IX	569	538	68.5	75.6	77.8	77.8
X	726	751	65.2	99.6	86.6	56.3
XI	523	533	69.8	70.1	73.7	73.7
XII	668	743	66.4	92.5	82.1	53.3

[a] In 1974 dollars.

1974 to $61.1 billion in 1985, with production expenses remaining relatively constant, net farm income rose $11 billion from the 1974 level of $37.6 billion to $48.5 billion. A similar pattern also exists for scenario VII, which assumes a supply shift of 2%.

Under the high demand scenario, demand for farm goods would grow at an annual rate of 3% through 1985 (scenarios IX–XII). This rate could be achieved with export demand growing at an annual rate of 10%, domestic population, 1%, real per capita disposable income increasing 3% per year, and the income elasticity of demand holding at 0.15. Due to the high demand, prices received and equilibrium output are considerably higher than under the moderate demand scenarios. Consequently, net farm income is also higher. This situation can best be described by considering a shift to the high demand scenario X from the most likely demand scenario VI. The prices received index under this high demand scenario increases 125 points, from 601 to 726 (1910–14 prices). The equilibrium quantity increases a little over $7 billion. Net farm income in real dollars increases $22.6 billion, while net farm income in current dollars increases as much as $34.7 billion, from $51.9 billion to $86.6 billion. However, if supply is allowed to shift at 2% per year (from scenarios X to XII), the prices received index will decline around sixty points while the equilibrium quantity increases almost $1 billion.

If population were to grow at the 1974 rate of 0.72%, if the growth in real per capita disposable income and domestic share of farm output remains at the 1967–74 average rate of 0.41% and 85%, respectively, and if export demand remains constant at the 1974 level, then we would have a 1.13% annual increase in demand. Results indicated that the farm sector could not continue to experience such a low demand without some financial problems, especially if supply was to shift at a 2% annual rate. Under the low demand and high supply scenarios (scenarios II and IV), real net farm income (in 1974 dollars) in 1985 drops below the 1974 simulated net farm income level. It is quite possible that export demand may drop below the 1974 level and result in a much lower demand shift, which in turn will depress prices received by farmers, equilibrium quantity, and net farm income. However, long before such depressed conditions for the farm sector came about, additional public programs would likely be considered. However, it is beyond the scope of this paper to analyze such policy issues and implications.

Summary

Based on previous studies and results in this study, one of the most realistic sets of supply and demand parameters appears to be demand elasticities of −0.15 in the short run and

−0.214 in the long run with an adjustment coefficient of 0.7 and supply elasticities of 0.20 in the short run and 1.0 in the long run with a long-run adjustment coefficient of 0.20. The most realistic scenario is considered to be a 1.6% shift in demand, a 1.14% shift in supply, and a 4% annual general price inflation. In addition, eleven other scenarios were identified as possible alternatives.

Simulations built around the above parameters and alternative scenarios suggest that as long as a strong demand persists, prices received by farmers and net farm income will maintain at reasonable levels. It is extremely difficult to maintain a reasonable price level if demand drops unexpectedly and/or supply suddenly increases due to good weather. Inflation may not have much impact on the prices received and farm income in the short run. However, in the long run the accumulated impacts of inflation on real net farm income is a serious problem.

It is beyond the scope of this paper to analyze policy alternatives, although this simulation model has the capacity to simulate alternative policies and varied rates of demand shift, supply shift, and inflation from year to year. This study further suggests that more research is needed in the area of aggregate demand and supply parameters for the food and fiber system at the farm level. Precise magnitudes of these parameters vary considerably among the existing publications and researchers.

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Spectral Analysis of Stochastic Properties in Regression: An Application in Supply Response Identification

Richard E. Just

This article demonstrates an empirical investigation of the applicability of the Nerlovian supply response model. Popular statistics, particularly those resulting from regression, may be inadequate and even misleading when a more general adaptive risk model is applicable. Because of the multidimensional nature of spectral tests, the frequency-domain approach is more robust. The empirical results present a case where popular statistics are misleading, but spectral results support the adaptive risk model. Even spectral techniques may be inadequate for distinguishing between the two models, but at least equal support for both models can be clear with spectral methods.

Key words: adaptive risk, Nerlovian model, spectral testing.

Spectral analysis of time series commonly finds four important areas of application in econometrics: (*a*) investigation of harmonic characteristics of sample time series (e.g., Rausser and Cargill), (*b*) investigation of effects of intertemporal transformation on time series (e.g., Hannan 1964, Nerlove 1964), (*c*) frequency-domain regression of time series and estimation of general distributed lag equations and equation systems (e.g., Hannan 1963, 1965; Wahba), and (*d*) investigation of stochastic specifications in regression. The investigation in (*d*) can be performed either in conjunction with the frequency-domain calculations of (*c*) or in an *ex post* sense after ordinary time-domain regression techniques have been applied. In the latter case the mean function (depending on exogenous variables) is first regressed from a time series, the spectral density of the estimated disturbance process is then computed, and assumptions relating to serial correlation in regression are then investigated (e.g., Anderson, chap. 10).

Applications in agricultural economics have thus far been almost entirely of the nature of (*a*) or the special cross-spectral analysis case of (*c*) and, as such, have been often criticized because of their lack of economic explanation.[1] The application of spectral analysis in this paper, however, corresponds to case (*d*) and thus demonstrates one use of spectral analysis in a model with economic content. Ordinary time-domain (rather than frequency-domain) regression methods are used because the general lag relationship estimated here is not a case included in the general model of (*c*) above. Spectral analysis is then used to investigate stochastic characteristics of regression equation disturbance processes. Due to the particular nature of this econometric investigation, the spectral results are further used to investigate hypotheses associated with several alternative econometric models. The empirical results, which pertain to the California field crop sector, are then used to demonstrate some general implications for estimation of the popular Nerlovian model. Results suggest that ordinary time-domain considerations in Nerlovian model estimation may not be sufficient to determine applicability because of the nature of an alternative lag model possibility that includes risk response. Apparently, unless more robust spectral methods are used, one may be led to

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[1] In theory, case (c) is a generalized distributed lag model and allows a great deal of economic explanation. However, applications have typically been only cross-spectral analyses and have thus considered only one independent variable (time series).

conclude that the Nerlovian model is applicable when in fact it is not. Even with the application of spectral analysis, the results may not be sufficient to discern between models. But, at least if not, the results indicate so. Several observations are also made with respect to the general problem of spectral hypothesis testing.

Empirical Discernment of Models

It is well known that for econometric purposes the Cagan adaptive expectations model differs from the Nerlovian partial adjustment model only in stochastic assumptions (Griliches, Zellner and Geisel). For example, where price (p_t) expectations are given by

$$p^*_t = \sum_{k=0}^{\infty} \beta(1-\beta)^k p_{t-k-1}, \qquad 0 < \beta < 1,$$

the Cagan model was originally specified as

$$(1) \quad y_t = a_0 + a_1 p^*_t + u_t, \qquad E(u_t) = 0, \quad E(u_t^2) = \sigma_u,$$

where u_t is a serially uncorrelated random disturbance (Cagan, Nerlove 1958). In the partial adjustment model, the assumption was that the desired value of the dependent variable follows the equation

$$(2) \quad y^*_t = a_0 + a_1 p_t + v_t, \qquad E(v_t) = 0, \quad E(v_t^2) = \sigma_v,$$

where v_t is a serially uncorrelated random disturbance (Nerlove 1958). Hence, where only a fixed percentage of the desired adjustment is accomplished each period, i.e., $y_t = y_{t-1} + \beta(y^*_t - y_{t-1})$, one obtains

$$(3) \quad y_t = \beta a_0 + \beta a_1 p_t + (1-\beta) y_{t-1} + v_t,$$

or, equivalently,

$$(4) \quad y_t = a_0 + a_1 p^*_t + (1-\beta) u_{t-1} + v_t,$$

where

$$u_t = \sum_{k=0}^{\infty} (1-\beta)^k \, v_{t-k}.$$

Thus, both equations (1) and (4) represent the same regression equation except that disturbances in equation (1) are serially uncorrelated, while those in equation (4) follow a first-order autoregressive process.

In subsequent work it has been generally acknowledged that verification of one set of stochastic assumptions or another does not give conclusive evidence regarding the underlying behavior mechanism. For example, it is possible that disturbances in the adaptive expectations model follow a first-order autoregressive process and cannot be distinguished from those in equation (4) (Zellner and Geisel). The assumptions in equations (1) and (4), as made above, lead to important differences in estimation procedures, at least with ordinary time-domain methods. In this paper one concern will be with discerning equation (1) from equation (4) empirically because of the associated implications for regression procedures. But it must be understood that the terms "adaptive expectations" and "partial adjustment" are used merely to describe the stochastic assumptions in equations (1) and (4) rather than the underlying behavioral influence.

To distinguish equation (1) from equation (4) on the basis of empirical results, both time-domain and frequency-domain approaches have been used. Zellner and Geisel use both maximum likelihood and Bayesian (time-domain) methods with consumption function data to estimate a model such as equation (3) under several alternative stochastic assumptions for v_t (possibly corresponding to equations (1) and (4)). Their results have served to emphasize the sensitivity of parameter estimates to parametric specification of the disturbance process and hence the need for determination of the appropriate model. Also, using consumption function data, Howrey has used the alternative approach of frequency-domain regression on the reduced forms of equations (1) and (4) (corresponding to equation (3)) from which estimates of disturbance spectra are produced directly (see (*c*) above). Howrey's results demonstrate the robustness of spectral analysis in the Zellner and Geisel problem because support is gained for an alternative not even considered in the earlier work. The problem in this paper involves an additional alternative that does not generally permit direct application of frequency regression. But an *ex post* application of spectral methods, such as suggested by Howrey's analysis of the Zellner and Geisel results, is possible and informative.

The empirical problem in this study differs from that considered by Zellner and Geisel and by Howrey because adaptive risk response is considered as an alternative to equations (1) and (4). Risk response has been a topic of growing interest in recent years, particularly with respect to microresearch. For example,

two invited paper sessions at the 1975 annual meetings of the American Agricultural Economics Association were devoted to risk response. The more general model that has been used econometrically is

$$(5) \qquad y_t = a_0 + a_1 p^*_t + a_2 s^*_t + u_t,$$

where u_t is serially uncorrelated and s^*_t is formed by geometrically weighting squares of observed price deviations from expectations

$$s^*_t = \sum_{k=0}^{\infty} \beta(1-\beta)^k (p_{t-k-1} - p^*_{t-k-1})^2$$

(King, Just 1975). The model in equation (5) is thus a generalization of the adaptive expectations model in equation (1), but the frequency regression methods advanced by Hannan (1965) and used by Howrey are no longer applicable because of the presence of squared terms in equation (5), even when equation (5) is expressed in reduced form.[2] Hence, following the general approach in Anderson (chap. 10), time-domain methods are used to estimate regression parameters, and spectral methods are used only in the analysis of residuals. Consistent methods of estimation for the parameters of equations (1) and (4) have been developed by Dhrymes when second sample moments exist asymptotically, and the method given by Just (1976) yields consistent estimators for the parameters in equation (5) when fourth sample moments of p exist asymptotically.[3]

[2] Even the modifications introduced by Howrey and Klein that deal with squared terms could not be employed without considerable truncation of the sums in equation (5) because the number of cross-product terms grows very rapidly as the maximum length of lag is increased. Indeed, upon expanding equation (5), one finds triple infinite summations of cross products of p. The time series in this study is likely far from long enough to adopt the necessary truncation required for this kind of frequency regression.

[3] These methods essentially consist of using the Klein transformation to treat all unobservable data as parameters to be estimated. Then ordinary or Aitkens regression procedures are used to perform a maximum likelihood search on β.

To demonstrate potential problems in empirically discerning the models in equations (1) and (4) from equation (5), data for wheat acreage response in the California San Joaquin Valley from 1949 through 1970 are used. The data are described in Just (1974). Hence, for the purposes of analysis, y_t in equations (1) through (5) represents acreage harvested. Because a time series of cost data was unavailable, the p_t variables represent only returns per acre (price × yield per acre). Also, because wheat production has been regulated by government programs (allotments and price supports) during parts of the last few decades, the estimated equations also include variables for the proportion of wheat program participation in terms of allotted acreages (z_t), the allotted wheat acreage on participating farms (g_t), and the price support for wheat times the proportion of wheat program participation (w_t). Using the estimation procedures indicated above, the (consistent) estimates for models (1), (4), and (5) in table 1 are obtained.

Since model (5) is rarely considered in studies such as this, suppose for a moment that only the results for equations (1) and (4) are available in table 1. With comparable fit, a common practice is to choose one model or the other depending on serial correlation statistics. In this case one would evidently be led to conclude that the Nerlovian model equation (4) is applicable since neither the Durbin-Watson statistic nor the serial correlation coefficient gives substantial evidence to the contrary.[4] The adaptive model in equation (1), on the other hand, appears inapplicable because of its inability to explain a seemingly autocorrelated disturbance process. The high

[4] Since equations are estimated in structural form (without lagged endogenous variables), the usual Durbin-Watson testing procedure can apply asymptotically. Although many other useful alternative statistics could also be considered, only the Durbin-Watson statistic is used for exemplary purposes because of its relative popularity.

Table 1. Estimated Wheat Acreage Relationships for the California San Joaquin Valley

Model	Constant	z_t	g_t	w_t	p^*_t	s^*_t	β	R^2	$\bar{R}^2$	D.W.	ρ^b
(1)	−1,369,612	−48,847	0.2579	46,389	30,941		0.059	0.7734	0.7008	1.0687	0.4414
	(534,412)[a]	(47,661)	(0.2402)	(21,042)	(10,983)						
(4)	−34,156	−46,277	0.2469	25,059	6,342		0.170	0.7712	0.6949	1.5650	−0.0066
	(51,721)	(45,949)	(0.2018)	(31,459)	(5,710)						
(5)	−3,602,852	−31,831	0.1706	14,694	90,732	−3,118	0.035	0.8740	0.8236	1.7349	−0.0140
	(764,017)	(37,037)	(0.1867)	(17,384)	(18,111)	(899)					

[a] Values in parentheses are standard errors from regressions conditioned on the maximum likelihood estimates of β.
[b] Values of ρ represent first-order autocorrelation among the $\hat{u}_t$ for models (1) and (5). In the case of model (4), ρ gives first-order autocorrelation among the prefiltered version of the $\hat{u}_t$, i.e., among the $\hat{v}_t$.

serial correlation coefficient and low Durbin-Watson statistic suggest that equation (4) may be a more appropriate model.

But another possibility exists. If equation (1) is estimated when equation (5) is applicable, then the residuals will actually be estimating

$$(6)\quad \begin{aligned} u^*_t &= u_t + a_2 \sum_{i=0}^{\infty} \beta(1-\beta)^i (p_{t-k-1} - p^*_{t-k-1})^2 - c_{u^*} \\ &= (1-\beta)u^*_{t-1} + a_2\beta(p_{t-1} - p^*_{t-1})^2 + u_t - (1-\beta)u_{t-1} - c_{u^*} \end{aligned}$$

if the term $a_2 s^*_t$ is not highly correlated with other variables in the model (where c_{u^*} is a constant that makes the expectation of u^*_t equal to 0 during the period of estimation). When the risk terms are not small relative to the true disturbance terms, the u^*_t process behaves very much like a first-order autoregressive process and thus leads to corresponding Durbin-Watson and serial correlation coefficients. In other words, if equation (5) applies, then estimation of the structural form in equation (1) or (4) will tend to produce residuals that behave the same way as the disturbances specified for equation (4) because of the low frequency nature of the risk variables that are excluded.

Although the results for equation (1) are sufficient to refute the simple adaptive expectation hypothesis, additional evidence is needed to distinguish between the partial adjustment mechanism and the adaptive risk mechanism. For this purpose a further comparison of equations (4) and (5) is needed. Considering the results in table 1, with respect to equation (5), it appears that positively correlated residuals in equations (1) and (4) are a result of risk response since the risk term is significant (asymptotically), fit is improved, the Durbin-Watson statistic is closer to 2, and serial correlation in residuals is reduced to near zero. Again, this may be an incorrect conclusion that gains support only because of the inadequacy of common time-domain statistics; that is, if u^*_t in equation (6) can have stochastic properties like the u_t disturbances in equation (4), then the reverse is also true. In each case the "autoregressive" parameter $(1 - \beta)$ in equations (4) and (6) is the same. Hence, if the model in equation (4) is applicable and equation (5) is estimated, the inclusion of s^*_t may have approximately the same effects as explaining the lagged u_{t-1} in equation (4). Consequently, the seemingly unexplained disturbances would be reduced approximately from $(1-\beta)u_{t-1} + v_t$ to v_t. When β is not near 1, as indicated by results in table 1, it is thus likely that fit will be improved, s^*_t will be significant, and because residuals more closely estimate v_t in equation (4), serial correlation will be reduced.

Hence, common time-domain statistics may be inadequate because of their highly composite nature. To gain information regarding possible departure from stochastic specifications hypothesized under each of the models in equations (1), (4), and (5), spectral analysis can be more useful because of its multidimensional nature.

Spectral Hypothesis Testing

Spectral methods in econometrics are most often applied to an observed time series (or a prewhitened, observed time series). But when regression is used, the disturbance series is only estimated, not observed. In a small sample situation, regression introduces serial dependence among estimated disturbances even when none exists among actual disturbances (because of the singularity of the distribution of the estimated disturbance vector). This same phenomenon will usually cause the covariance-stationary assumption of spectral analysis to be violated.[5] But, asymptotically, disturbances are consistently estimated, and necessary assumptions of spectral analysis are satisfied if true disturbances are covariance stationary. Hence, ordinary spectral techniques become asymptotically applicable for equations (1), (4), and (5) since the associated disturbance processes are covariance stationary.

The spectral density function of a covariance-stationary process $\{u_t\}$ is defined by

$$(7)\quad f(\lambda) = \frac{1}{2\pi} \sum_{h=-\infty}^{\infty} c_{uu}(h) e^{-i\lambda h}, \qquad -\infty < \lambda < \infty,$$

and describes the density of variance of the $\{u_t\}$ process over frequency λ.[6] Since the

[5] Covariance stationarity of a time series $\{u_t\}$ implies a constant mean, $E(u_t) = c_u$ for c_u constant, as well as a covariance function that is independent of t, $\mathrm{cov}(u_t, u_{t+h}) = c_{uu}(h)$. Note that $c_{uu}(h) = c_{uu}(-h)$.

[6] Frequency (angular frequency) represents cycles per unit time (multiplied by 2π). One-half cycle per time period corresponds to

spectral density function of different order autoregressive and/or moving average processes is distinctly different, the spectral density in equation (7) can be used to determine the stochastic structure of the $\{u_t\}$ process. The spectral density function is estimated by substituting the sample covariance function,

$$\hat{c}_{uu}(h) = \frac{1}{t_f - t_0 + 1} \sum_{k=t_0}^{t_f - |h|} u_k u_{k+|h|},$$

for $c_{uu}(h)$ in equation (7). The estimate so obtained is called the sample periodogram and is denoted here by $\hat{f}(\lambda)$. The periodogram is usually computed only at points $\lambda = 2\pi j/T, j = 1, \ldots, [T/2]$, where $T = t_f - t_0 - 1$, to allow use of fast Fourier transform algorithms and because estimates at those intervals are asymptotically independent. (The results indicated here are derived in Brillinger and in Jenkins and Watts.) Since $f(\lambda)$ can be represented as

$$(8)\quad \hat{f}(\lambda) = \frac{1}{2\pi T} |d_u(\lambda)|^2,$$

$$d_u(\lambda) = \sum_{t=1}^{T} u_{t_0+t-1}\, e^{-i\lambda t},$$

the complex central limit theorem implies asymptotic complex normality of $d_u(\lambda)$,[7] $d_u(\lambda) \to N_c[0, 2\pi T f(\lambda)]$, $\lambda \neq 0, \pm\pi, \pm 2\pi, \ldots$. Hence, the square has a chi-square distribution (asymptotically),

$$(9)\quad \frac{2\hat{f}(\lambda)}{f(\lambda)} \to \chi^2_{(2)}, \ \lambda \neq 0, \pm\pi, \pm 2\pi, \ldots$$

At $\lambda = 0, \pm\pi, \pm 2\pi, \ldots$, similar results hold except that either the real or complex component of $d_u(\lambda)$ vanishes and the chi-square distribution in equation (9) loses one degree of freedom.

A spectral hypothesis test based on these distributional results can be applied easily to the output (periodogram) from standard computer programs. The important property of the periodogram, which makes this possible, is the asymptotic independence of periodogram ordinates $\hat{f}(\lambda_j)$, $\lambda_j = 2\pi j/T, j = 0, 1, \ldots, [T/2]$.[8] With mutual independence, a periodogram can be regarded as a multidimensional statistic for which the significance probabilities can be determined independently in each dimension. Let the spectral hypothesis be given by H_0: $f(\lambda) = f_0(\lambda)$ for some specified spectral density function $f_0(\lambda)$. Suppose that an upper limit θ_j and a lower limit ϕ_j are specified for each periodogram ordinate and that the null hypothesis is rejected if any periodogram ordinate falls outside its limits. The critical region of the test is then given by

$$c = \{\hat{f}(\lambda): \hat{f}(\lambda_j) > \theta_j \text{ or } \hat{f}(\lambda_j) < \phi_j,\ j = 1, \ldots, [T/2] - 1\}.$$

With independence of the periodogram ordinates, the significance level of the test or the probability of the critical region under H_o is[9]

$$(10)\quad \alpha \equiv P\{c | f(\lambda) = f_0(\lambda)\} = 1 - \prod_{j=1}^{[T/2]-1} P\{\phi_j \le \hat{f}(\lambda_j) \le \theta_j | H_0\}.$$

Using the results in equation (9), which indicate an asymptotic chi-square distribution, and replacing $f(\lambda)$ by the specified $f_0(\lambda)$ under H_0, the calculations in equation (10) can be easily made,[10] and the θ_j and ϕ_j can be chosen to attain a specified significance level.[11]

One reasonable approach, where no specific alternatives are of interest, is to choose the θ_j and ϕ_j to equate the probabilities of the acceptance region of periodogram ordinates. This implies

$$(11)\quad (1-\alpha)^{1/([T/2]-1)} = P\{\phi_j \le \hat{f}(\lambda_j) \le \theta_j | H_0\},$$
$$= P\left\{ \frac{2\phi_j}{f_0(\lambda_j)} \le \frac{2\hat{f}(\lambda_j)}{f_0(\lambda_j)} \le \frac{2\theta_j}{f_0(\lambda_j)} \,\middle|\, H_0 \right\}, \quad j = 1, \ldots, [T/2] - 1.$$

$\lambda = \pi$, one-fourth cycle per time period corresponds to $\lambda = \pi/2$, etc.

[7] A complex random variable $x = v + iw$ has a complex normal distribution with mean $E(x) = E(v) + iE(w)$ and variance $\sigma_x = E[(x - Ex)(x - Ex)] = \sigma_v + i\sigma_w$ if $(vw)'$ has a two-dimensional multivariate normal distribution with mean $(EvEw)'$ and covariance matrix

$$\frac{1}{2}\begin{bmatrix} \sigma_v & \sigma_w \\ \sigma_w & \sigma_v \end{bmatrix}$$

[8] Here, $[T/2]$ represents the largest integer less than or equal to $T/2$.

[9] An alternative procedure has been used by Naylor, Wertz, and Wonnacott in testing hypotheses about the spectra of simulated processes. But their method provides only a bound on α that is such that their tests are always biased toward acceptance. The method in equation (10), however, is asymptotically exact.

[10] Although it is also well known that $\hat{f}(\lambda)/f(\lambda) \to \chi^2_{(1)}$ for $\lambda = 0, \pm\pi, \pm 2\pi, \ldots$, to avoid unnecessary complications in the asymptotic tests that are outlined in this paper, these end points will be disregarded. Their potential contribution is asymptotically unimportant, anyway.

[11] However, equation (10) does not determine ϕ_j and θ_j uniquely. Thus, ϕ_j and θ_j can be chosen to attain high power against alternative hypotheses of interest. Although the power of this chi-square test can be easily calculated for the specific alternative hypothesis using the distribution in equation (8), a discussion of the problems associated with maximizing power must be left for another paper.

Since $2\hat{f}(\lambda_j)/f_0(\lambda_j)$ has the distribution in equation (8) under H_0, the significance points ϕ_j and θ_j can be determined using chi-square significance tables when σ^2 is known,[12]

$$(12) \quad \frac{2\phi_j}{f_0(\lambda_j)} = \bar{\phi} \equiv \chi_{(2;1-\alpha^*)},$$

$$\frac{2\theta_j}{f_0(\lambda_j)} = \bar{\theta} \equiv \chi^2_{(2;\alpha^*)},$$

where $\alpha^* = \frac{1}{2}(1-\alpha)^{1/([T/2]-1)}$ and $\chi^2_{(n;\alpha)}$ is the α significance point of the chi-square distribution with n degrees of freedom. Hence, the chi-square testing procedure, which will be followed in this paper, corresponds to the following. First, draw an upper horizontal line at θ and a lower horizontal line at $\bar{\phi}$. If the simple path of $2\hat{f}(\lambda)/f_0(\lambda)$ crosses either the upper line or the lower line, then the hypothesis is rejected; otherwise, it is not.

If one is testing a null hypothesis of serial independence, then this test is particularly easy to perform since $f_0(\lambda) = \sigma^2/2\pi$ and is constant. Hence, on the basis of equations (11) and (12), one need only observe whether any $\hat{f}(\lambda_j)$ falls outside the single interval—say, $(\bar{\phi}, \bar{\theta})$—where $\theta = \theta_j$, $\phi = \phi_j$ for all $j = 1, \ldots, [T/2] - 1$. If a spectral estimator is computed by averaging adjacent periodogram ordinates (windowing), then the significance points can be determined with essentially the same calculations as above except that the degrees of freedom in the chi-square distribution would change (by a factor of the number of ordinates averaged). If σ^2 is unknown, then equations (11) and (12) still apply asymptotically when σ^2 is replaced by its estimate from regression results.

Another approach to spectral hypothesis testing, developed by Durbin, deals with the empirical spectral distribution function (the cumulated periodogram). Since appropriate modifications have been made in Durbin's method for the case where disturbances are only estimated by regression, his results usually find exact applicability in ordinary small sample regression. But in the applications in this paper, Durbin's method also applies only asymptotically since only asymptotic properties are obtained with each of the regression procedures that are employed. The null hypothesis that Durbin considers explicitly is H_0: $f(\lambda) = \sigma^2/2\pi$, which corresponds to serially uncorrelated regression disturbances as in models (1) and (5). But to consider other null hypotheses, his method can be easily modified by dividing the raw periodogram ordinates by their corresponding hypothesized values before cumulating. Yet, another approach—one that is used here—is to prefilter (or prewhiten) the time series so that the hypothesized spectrum corresponds to white noise in the filtered series.[13]

The test statistic suggested by Durbin is the estimated spectral distribution function (the normalized, cumulative periodogram),

$$(13) \quad \hat{F}(\lambda_j) = \sum_{i=1}^{j} \hat{f}(\lambda_i) \Bigg/ \sum_{i=1}^{[T/2]} \hat{f}(\lambda_i),$$

$$\lambda_j = \frac{2\pi j}{T}, j = 1, \ldots, [T/2].$$

Durbin has derived slight modifications of the usual Kolmogorov-Smirnov statistics that are necessary for small sample tests on the cumulated periodogram (computed from true disturbances). His test involves calculating lines of the form $y = c_0 + 2j/T$, where c_0 is a constant determined from significance tables. If the sample path of $\hat{F}(\lambda_j)$ crosses the line(s), then the hypothesis of serial independence is rejected; otherwise, it is not. In later work he has made modifications for the case where the periodogram is computed from least-squares residuals, which involve calculating a pair of parallel lines for a one-sided test or two pairs of parallel lines for a two-sided test. If the sample path of $\hat{F}(\lambda_j)$ crosses neither line of the pair(s), the hypothesis of serial independence is not rejected; if it crosses both lines of the pair(s), the hypothesis is rejected; if it crosses only one line of the pair(s), the test is inconclusive.[14] The upper line in each pair is calculated by

$$(14) \quad y = c_0 + \frac{2j}{(T-k)}, \quad 0 \le j \le \frac{(T-k)}{2},$$

where k is the number of regressors including the constant term. The lower line is given by

[12] Although not necessarily more powerful, the usual practice of dividing chi-square probabilities of rejection equally among high and low points is followed here.

[13] A time series $\{Y_t\}$ is a prewhitened version of $\{X_t\}$ if $\{Y_t\}$ is generated by

$$Y_t = \sum_{k=0}^{K} a_k X_{t-k}$$

for some constants a_k, $k = 0, \ldots, K$. For example, if $\{X_t\}$ is a first-order autoregressive process with autoregressive parameter ρ, then $Y_t = X_t - \rho X_{t-1}$ is serially uncorrelated (white noise).

[14] Although the significance points are only approximated by Durbin's methods when T or k are even, he argues that the error of approximation is negligible.

$$(15)\quad y = c_0 + \frac{2[j - (k-1)/2]}{(T-k)}, \qquad \frac{(k-1)}{2} \leq j \leq \frac{T}{2}.$$

Again, the c_0 term is associated with the significance level of the test and is determined from significance tables developed by Durbin.

In the case of ordinary regression, the Durbin test has the advantage of small sample applicability. But in any case the former chi-square test is usually easier to perform in practice because only the $\hat{f}(\lambda_j)$ in equation (8) rather than the $\hat{F}(\lambda_j)$ in equation (13) are usually obtained through standard computer software.

Some Empirical Results

Following estimation of the three equations (1), (4), and (5), as reported in table 1, consistent estimates of the disturbances were calculated for each model. In each case the periodogram in equation (8) was computed, and the corresponding sample spectral distribution function in equation (7) was also determined. The periodograms are shown in figure 1, and the corresponding sample distribution functions are shown in figure 2. In each case results are shown for the test of $H_0: f(\lambda) = \sigma^2/2\pi$ against the alternative $H_1: f(\lambda) \neq \sigma^2/2\pi$ with significance level $\alpha = 0.10$.[15] The significance points ϕ_j and θ_j, determined according to equation (12), are indicated with broken lines in figure 1. The significance lines in equations (14) and (15) are indicated with broken lines in figure 2. The upper pair of lines in each case corresponds to Durbin's one-sided test for excess low frequency, and the lower pair of lines corresponds to Durbin's one-sided test for excess high frequency. As Durbin indicates, the two one-sided tests can be combined to form a two-sided test with almost no loss in accuracy.

Again, the null hypothesis of serial independence must be rejected for the model in equation (1) as indicated by the statistics in table 1. Consider, the second alternative model—the partial adjustment equation in equation (4). Since the partial adjustment model corresponds to the adaptive expectations model except that disturbances are serially correlated, the spectral estimates from equation (1) in figures 1 and 2 provide some evidence for or against the partial adjustment model. The disturbance in equation (4) is a first-order autoregressive process. Apparently, the results for equation (1) are not inconsistent with the spectral shape of a first-order autoregressive process, e.g., one with excessive low frequency noise. To further investigate this possibility, the spectral results corresponding to equation (4) are useful. Here, the estimated disturbances in equation (4) were prefiltered to obtain estimates of v_t. Hence, under the usual partial adjustment specifications, the spectrum corresponding to equation (4) in figures 1 and 2 should be white noise. But apparently the spectral results do not highly favor the partial adjustment model. The chi-square test in figure 1 indicates rejection of the hypothesis corresponding to model (4), while the Durbin test in figure 2 leads neither to rejection nor acceptance.

Finally, consider the adaptive risk model in equation (5). Again, the hypothesized spectrum of regression disturbances is white noise. In this case both spectral testing methods in figures 1 and 2 lead to definite nonrejection of the spectral test corresponding to the adaptive

[15] Consistent estimation is only required under the null hypothesis. The hypothesis tests continue to apply, as in all statistical problems, even though the parameters may be estimated biasedly under the alternative hypothesis.

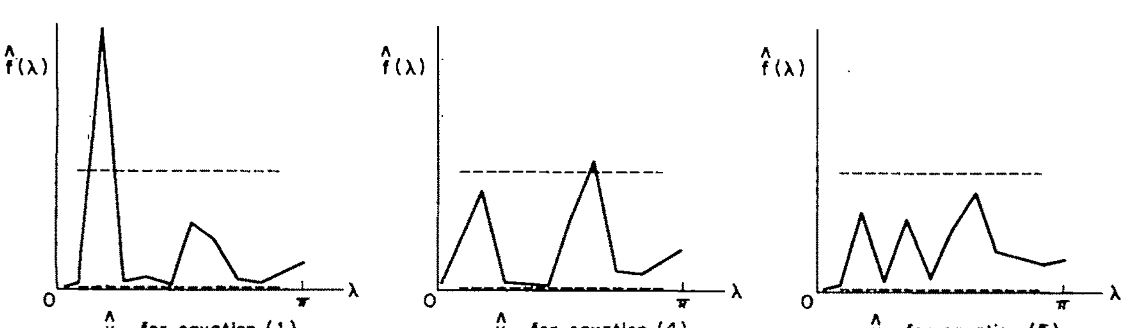

Figure 1. Estimated spectral densities for wheat acreage in the San Joaquin Valley

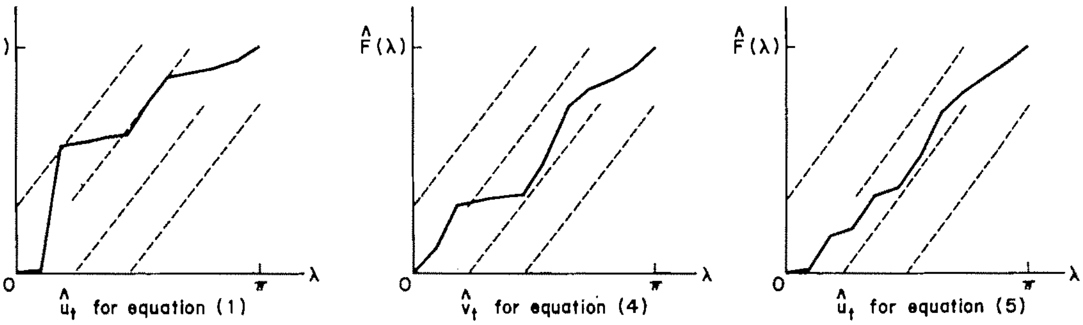

Figure 2. Empirical spectral distribution functions for wheat acreage in the San Joaquin Valley

risk model. Hence, in this particular empirical problem, spectral methods are apparently sufficient to provide some evidence for one model over another.

But it is not necessarily the case that spectral methods will lead to support of only one model or another. Based on the same arguments as those pertaining to the time-domain statistics above, it is possible that spectral tests will simultaneously support both models (4) and (5). This has indeed been found to be the case in a similar study of wheat acreage response in the Sacramento Valley of California. The particular empirical problem in this paper demonstrates that spectral methods can possibly lead to evidence supporting only one model in cases where time-domain methods are not conclusive. Furthermore, even though time-domain statistics appear conclusive, the arguments of this paper suggest that they may be misleading considering the types of alternatives that possibly exist. For example, one would expect tests based on the Durbin-Watson statistic or serial correlation coefficient to have an extremely low power against the alternative disturbance process in equation (6). For robustness, an application of spectral analysis appears advisable whenever the Nerlovian model is employed.

Another observation suggested by the results is that extensive testing (possibly including spectral methods and frequency-domain regression), with respect to geometric or general linear lag models under alternative stochastic specifications, may not be sufficient to conclude in favor of their applicability when alternatives such as equation (5) may also exist. The studies by Zellner and Geisel and by Howrey represent such attempts. Nonlinear lag models such as equation (5) are not usually considered in macroeconomic problems, but if they can possibly apply, then the conclusions by Zellner and Geisel and by Howrey, which favor a first-order autoregressive scheme, should perhaps be reconsidered. It seems that similar methods applied to microeconomic relations cannot be fully conclusive.

Conclusions

The results in this paper imply that empirical discernment of the Nerlovian partial adjustment model from an adaptive risk model is a delicate problem. If either model is operative, then time-domain estimation results for equation (4) alone (or possibly a comparison with results for equation (1)) will likely lead one to conclude in favor of the partial adjustment model. If time-domain results are also obtained for (5), then one would likely be led to conclude in favor of the adaptive risk model, again when either equation (4) or (5) are applicable. A further investigation with spectral analysis leads to more appropriate conclusions. In the empirical problem in this paper, spectral results favored the adaptive risk model. In general, it is possible that spectral results could equally support both models, i.e., both associated spectral hypotheses could be supported. Hence, empirical discernment would not be possible; but at least results would make clear the possible applicability of both models.

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Notes

Welfare and Exchange Rate Effects of the Rhodesian Trade Embargo: An Elasticity Approach

Ewen M. Wilson and Paul R. Johnson

Trade embargoes, like wars, floods, and other catastrophes, put severe pressures on an economy. The response to such pressures is necessarily of considerable magnitude. The eleven-year-old trade boycott of Rhodesia, initiated by the British and sanctioned by the United Nations, provides an observation of such a response.[1] The observation is of interest since Rhodesia, a relatively small country, depends on exports of agricultural and mineral resources for a substantial fraction of her economic activity. Furthermore, the response has involved rather stringent foreign exchange controls and the maintenance of an overvalued exchange rate. The importance of the exchange rate as an economic policy variable has been forcefully expounded by Schuh. Many African countries maintain overvalued currencies (Haessel and Vickery). The exchange rate response and the cost (defined below) of the Rhodesian trade boycott is the subject of this analysis, which follows an elasticity approach.

Elasticity techniques have been increasingly used in recent years to analyze balance of payments, exchange rate, and welfare effects of international trade distortions (Floyd, Basevi, Walker, Johnson). Basevi's work on the exchange rate and welfare effects stemming from import tariffs and Walker's generalization of the latter work to analyze bilateral tariffs offer an appropriate analytical framework for the task at hand. However, we have converted the Basevi-Walker model to account for special peculiarities of the present study and to generate otherwise nonestimable price effects of the trade embargo on the Rhodesian import market. Welfare effects are viewed solely from the Rhodesian perspective and refer, following Basevi's definition, to import consumers' utility (area under the import demand curve) minus the cost of resources employed in the export market (area under the export supply curve). The layout of this paper, which is based on work by Wilson, is as follows. First, special peculiarities of the Rhodesian situation are discussed and assumptions made; second, the algebraic model is outlined; and third, empirical results are presented along with some conclusions.

Peculiarities and Assumptions

Historically, the Rhodesian economy has been trade oriented with export revenues accounting for approximately 45% of the gross national product (GNP) prior to 1966. Flue-cured tobacco exports, the single largest component of the foreign trade accounts, had by the 1960s established Rhodesia as a major supplier of unmanufactured tobacco, next to the United States. By virtue of this large share in world trade, Rhodesia may be assumed to face a less than perfectly elastic foreign demand for her tobacco exports; for exports other than tobacco and for imports the standard small country assumptions (infinite elasticities of import supply and export demand) presumably hold.[2]

The foreign trade policies of the Rhodesian authorities, based on observed response to the economic boycott, are assumed to be directed toward preservation of balance of payments equilibrium and exchange rate parity (essentially via foreign exchange quotas). The trade ban may be viewed from the Rhodesian perspective as a leftward (downward) shift of the export demand curves and an upward shift of the import supply curve. The vertical distance between the pre- and postembargo import supply curves (resulting partly from the ban on goods destined for Rhodesia and partly from Rhodesian import restrictions to preserve balance of payments equilibrium and exchange rate parity) reflects a price effect to Rhodesian importers. From the viewpoint of Rhodesia's trading partners, the trade ban represents a movement along their demand curves for Rhodesian goods, prompted by a leftward shift in the supply curve of Rhodesian goods. The vertical distance between pre- and post-

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[1] The trade ban was initially imposed by Britain's Labor government in retaliation for the 11 November 1965 Unilateral Declaration of Independence by Rhodesia from Britain. In December 1966, the trade ban was extended by United Nations Security Council Resolution 232 on grounds of Rhodesia's "threat to international peace and security."

[2] These assumptions are equivalent to Basevi's "third case" (Basevi, p. 844). However, the comparison cannot be pursued very much further owing to the different interpretation given the model as discussed below.

embargo export supply curves is a measure of the export price effect of sanctions stemming from the decision of the world community to penalize trade with Rhodesia. In a sense the price effect in the export market is analogous to a foreign tariff on Rhodesian goods and reflects the risk of international penalty for "sanctions busting," "middlemen" fees for undercover trading operations, and so forth.[3]

The Algebraic Model

The analytic problem may be formulated in terms of a simple demand and supply model:

$$(1) \quad S_t = S_t(P_t^d),\ S_o = S_o(P_o^d),\ S_m = S_m(P_m^f),$$

and

$$D_t = D_t(P_t^f),\ D_o = D_o(P_o^f),\ D_m = D_m(P_m^d),$$

where S and D refer to quantities supplied and demanded, respectively, P refers to price, d is domestic currency values, f is foreign currency values, t is flue-cured tobacco exports, o is other exports excluding tobacco, and m is imports. More precisely, the supply and demand functions refer to excess supply and excess demand. The supply of exportables, after domestic demand has been accounted for, represents an excess export supply and is functionally related to domestic currency prices. The foreign demand for exports represents an excess demand after foreign supplies have been accounted for and is functionally related to foreign currency prices. Likewise, excess (domestic) demand for imports is a function of domestic currency prices, while excess (foreign) supply of imports is a function of foreign currency prices.

Foreign and domestic currencies are linked by the exchange rate

$$(2) \qquad \pi = P^d/P^f.$$

Changes in the exchange rate may be viewed as a shift of one or other of the curves depending on which currency the market is denominated in. For instance, when the export market is denominated in terms of domestic currency, devaluation (an increase in the domestic price of foreign currency) shows as a rightward shift of the export demand curve along the export supply curve (since export demand is functionally related to the adjusted foreign currency price). Likewise, in a domestic currency denominated import market, devaluation shows as an upward shift of the import supply curve along the unshifting import demand curve.

The balance of trade identity may be written in terms of domestic currency units as

$$(3) \qquad B = P_t^d X_t + P_o^d X_o - P_m^d M,$$

where B refers to the balance of trade, and X and M refer to exports and imports, respectively.

The price effect of the trade embargo on the Rhodesian import market is denoted by t_m, and the price effect in the export market is denoted by t_t for flue-cured tobacco and t_o for all other exports. Given a knowledge of respective demand and supply elasticities and based on ex post declines in export volumes, the magnitudes of t_t and t_o are easily approximated.[4] The derivation of t_m is more complex, since under our assumptions it depends not only on import market elasticities but also upon the magnitudes of t_t, t_o, and export market elasticities. The method employed to solve for t_m is based on algebraic manipulation of the balance of trade identity (3). Concerned as this study is with finite magnitudes, it is necessary to write the total differential of (3) in terms of the finite approximation

$$\begin{aligned}(4) \quad \Delta B &= P_t^d\, \Delta X_t + X_t\, \Delta P_t^d + P_o^d\, \Delta X_o \\ &\quad + X_o\, \Delta P_o^d - P_m^d\, \Delta M - M\, \Delta P_m^d \\ &\quad + \Delta P_t^d\, \Delta X_t + \Delta P_o^d\, \Delta X_o - \Delta P_m^d\, \Delta M.\end{aligned}$$

By following Basevi and Walker, making use of the foreign exchange rate identity (2), and choosing initial units such that prices and the foreign exchange rate equal unity, it is possible by utilizing the differential of the exchange rate identity (with higher order differences ignored) to transform equation (4) to an expression including slopes of respective demand and supply curves, percentage exchange rate change $\Delta\pi/\pi$, and sanctions price effects, t_t, t_o, and t_m. Our derivation also incorporates the profit-maximizing rule of equality of marginal revenue with marginal cost. By setting $\Delta B = \Delta\pi/\pi = 0$ and by converting to elasticities, it can be shown that

$$\begin{aligned}(5) \quad t_m &= \{X_t\eta_t\epsilon_t(1 + \eta_t)/M\eta_m Z^2\}t_t^2 \\ &\quad - \{X_t\eta_t[1 + \epsilon_t(1 + \eta_t)]/M\eta_m Z\}t_t \\ &\quad + \{X_o\epsilon_o/M\eta_m\}t_o^2 - \{X_o(1 + \epsilon_o)/M\eta_m\}t_o,\end{aligned}$$

where $Z = \eta_t - \epsilon_t(1 + 1/\eta_t)$, and η and ϵ are, respectively, demand and supply elasticities.[5]

Having obtained estimates of t_t, t_o, and t_m, it is a relatively simple matter to revert to the Basevi-Walker framework for estimating welfare costs and

[3] The tariff analogy is not quite so neat in the import market since here the price effect stems from two sources: first, the extra trading cost to foreigners emanating from the risk of selling goods to Rhodesia, and second, the Rhodesian import restrictions imposed to maintain balance of payments equilibrium and avert devaluation of the Rhodesian currency. In actual fact Rhodesian import restrictions primarily involved rationing of reduced foreign exchange earnings. Hence, this study can abstract itself from distribution and transfer questions that would arise under an explicit policy of retaliatory import tariffs. In order to avoid confusion, the remainder of this study will refer to "price effects" in the import and export markets rather than tariffs per se. Nevertheless, the tariff analogy may be helpful to readers accustomed to thinking in terms of the original Basevi-Walker model.

[4] Perhaps it should be stated that the embargo on Rhodesian exports was far from totally effective. A total embargo implies X_t and X_o equal 0, a situation that would make the following analysis redundant.

[5] Base prices in these elasticities are defined exclusive of export and import market price effects. For instance, the export demand elasticity for flue-cured tobacco, $\eta_t = \Delta D_t(P_t^f)P_t^f/\Delta P_t^f X_t$.

exchange rate effects of the economic boycott. This analysis is couched in terms of total elimination of t_t, t_o, and t_m (that is, $\Delta t_t = -t_t$, $\Delta t_o = -t_o$, and $\Delta t_m = -t_m$). Starting once again with equation (4), employing the same assumptions, setting $\Delta B = 0$, converting to elasticities, and solving for $\Delta\pi/\pi$ yields the exchange rate effect of a return to "normal" (preembargo) trading patterns. The solution is a quadratic equation in $\Delta\pi/\pi$, which for notational simplicity is rewritten as $\dot{\pi}$:

$$(6)\quad \dot{\pi}^2 \{X_tK_t/M + X_o\epsilon_o/M - A_m\} + \dot{\pi} \{X_t[2K_tt_t + A_t]/M + X_o[2\epsilon_ot_o + (1 + \epsilon_o)]/M + A_m(t_m - 1) - 1\} + \{X_tt_t[K_tt_t + A_t]/M + X_ot_o[\epsilon_ot_o + (1 + \epsilon_o)]/M + A_mt_m\} = 0,$$

where $K_t = \eta_t\epsilon_t(1 + \eta_t)/T_t^2$, $A_t = \eta_t[1 + \epsilon_t(1 + 1/\eta_t)]/T_t$, $T_t = \eta_t - \epsilon_t(1 + 1/\eta_t)(1 + t_t)$, and $A_m = \eta_m/(1 + t_m)$.[6] Based on the Basevi-Walker definition of welfare, we are interested in measuring the areas in the import market

$$(7)\qquad \int D_m(P_m{}^d)\, dM,$$

and in the export market

$$(8)\qquad \int S_t(P_t{}^d)\, dX_t + \int S_o(P_o{}^d)\, dX_o.$$

Thus, the net welfare effect of lifting the embargo is given by the gain in the import market—equation (7)—minus the loss in the export markets—equation (8). By substituting the appropriate terms used in deriving equation (6), it may be shown that the welfare effect is

$$(9)\quad W = MA_m(\dot{\pi} - t_m)[1 + 0.5(\dot{\pi} + t_m)] - X_t\epsilon_t(1 + \eta_t)(\pi + t_t)[(1 + 1/\eta_t) + 1/\eta_t)(\pi + t_t)/2T_t]/T_t - X_o\epsilon_o(\pi + t_o)[1 + 0.5(\pi + t_o)],$$

where the exchange rate effect ($\dot{\pi}$) is derived from equation (6).

Empirical Results and Conclusions

Due to restrictions on publication of post-1965 production and trade data, elasticity parameters are assumed constant for the pre- and postembargo situations. The Rhodesian flue-cured tobacco export demand elasticity (η_t) was estimated as -5.2 and the export supply elasticity (ϵ_t) as 0.73 (Wilson). For the supply elasticity of other exports and for the import demand elasticity, plausible values are selected and bounds set on these choices (viz., $\epsilon_o = 0.8$, 1.5, and 2.5; $\eta_m = -0.5$, -1.0, and -1.5).[7] Preembargo trade data (in millions of Rhodesian dollars) is taken as $X_t = 84.9$, $X_o = 226.7$, and $M = 233.3$ (mean 1964–65 data).[8] For the postembargo period, 1966–71, assuming constant export shares, the mean values are $X_t = 63.909$, $X_o = 172.791$, and $M = 225.5$. The sanctions price effect parameters, t_t and t_o, are computed from median elasticity values based on the 24% decline in exports (mean 1966–71 compared with preembargo). Upper and lower estimates of these parameters are also obtained based on the decline in mean export values from preembargo to 1966–68 (35% decline) and 1969–71 (13% decline), respectively. This yields $t_t = 0.20$, 0.38, and 0.55 and $t_o = 0.09$, 0.16, and 0.23.

The number of combinations of the elasticity and price parameters in equations (5), (6), and (9) is eighty-one. A summary of the outcomes is presented in table 1 for median, pessimistic, and optimistic parameter combinations and for the mean of all eighty-one outcomes.

There are two interpretations of the results in table 1. First, the welfare gain resulting from a resumption of preembargo trade,[9] in which case the exchange rate effect may be viewed as a potential appreciation of the Rhodesian currency. Second, the welfare cost of the status quo, in which case the exchange rate effect represents the level of overvaluation of the Rhodesian dollar. Since businessmen in Rhodesia have been complaining about a "shortage" of foreign exchange, the second interpretation is preferred. Thus, based on the median parameter outcome and also on the mean of all outcomes, the annual welfare cost to Rhodesia in the 1966–71 period was close to 80 million Rhodesian dollars. This is equivalent to about 7% of 1971 GNP. By the same token, the 1971 rate of overvaluation of the Rhodesian dollar was probably 8% to 10%, while the import price index was approximately 60% above its 1964–65 level. Under the most pessimistic combination of elasticity parameters, the welfare cost to Rhodesia amounted to less than 23% of 1965 GNP and less than 14% of 1971 GNP.

In the period since 1971, exchange rate pressures appear to have intensified in Rhodesia. The so-called "shortage" of foreign exchange has become more acute. The term "shortage" is of course a price-related concept: at a given price, demand for foreign currencies is greater than the supply forthcoming. The implication is that the price of foreign currencies in terms of Rhodesian dollars is too low, or what amounts to the same thing, the Rhodesian dollar is overvalued. Based on the empirical evidence presented here, the recent level of overvaluation has probably been well in excess of 10%. Black-market currency operations and frequent violations of Rhodesian foreign exchange regulations are further evidence of overvaluation. The overval-

[6] Base prices in these elasticities are defined inclusive of export and import market price effects. For instance, the export demand elasticity for flue-cured tobacco, $\eta_t = \Delta D_t(P_t^f)P_t^f/(1 + t_t)/\Delta P_t^f X_t$.

[7] Plausible does not mean pulled out of the air. These ranges are consistent with earlier empirical applications (Floyd, Basevi, Johnson) and with Harberger's "rule of thumb" (Harberger, p. 521).

[8] Since the model initially assumes prices and the exchange rate equal to unity, trade value data are synonymous with X_t, X_o, and M.

[9] Abstracting from the structural readjustments that have occurred in the post-1965 period.

Table 1. Estimates of Import Price, Exchange Rate, and Welfare Effects of the Rhodesian Embargo

Parameter Values	Implicit Import Price Effect, t_m (%)	Exchange Rate Effect, $\hat{\pi}$ (%)	Welfare Effect, W (million Rh $ per year)	Welfare Effect as Percentage of GNP 1965	1971
Median[a]	52.38	−8.24	79.8	11.1	6.9
Mean	64.41	−10.93	83.8	11.7	7.2
Pessimistic[b]	177.42	−27.79	158.1	22.1	13.6
Optimistic[c]	16.54	−0.04	33.3	4.7	2.9

[a] $\epsilon_e = 1.5$, $\eta_m = -1.0$, $t_t = 0.38$, and $t_e = 0.16$.
[b] $\epsilon_e = 2.5$, $\eta_m = -0.5$, $t_t = 0.55$, and $t_e = 0.23$.
[c] $\epsilon_e = 0.8$, $\eta_m = -1.5$, $t_t = 0.20$, and $t_e = 0.09$.

ued Rhodesian dollar provides a powerful incentive for illegal foreign exchange transactions, particularly since legal, though arbitrary, foreign currency allocations have distorted the import market.

The fact that Rhodesian authorities have chosen to support an overvalued currency may seem paradoxical. The overvalued Rhodesian dollar is equivalent to a tax on exports; it increases the foreign currency price of Rhodesian exports and thereby reduces their competitive trading position. However, it also maintains import prices at a level below that defined by exchange rate equilibrium. If import demand elasticity is less than unity, the lower price for imports will result in a reduced total domestic currency cost of imports. Evidently, the Rhodesian authorities perceive this to be the case and feel that lower domestic currency import costs outweigh the foreign currency earnings potential of increased agricultural and mineral exports. In other words, they hold that elasticity magnitudes are not sufficient for the Marshall-Lerner condition to be met.[10] However, based on elasticity values employed here, this perception is incorrect. Naturally, the present exchange rate policy has income distribution implications within the Rhodesian economy.

[10] In terms of our notation the Marshall-Lerner conditions states that depreciation of the Rhodesian currency reduces balance of payments pressure (improve the balance of payments) so long as η_m (absolute) plus the trade weighted sum of ϵ_t and ϵ_e is greater than unity.

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The Effects of Income, Assets, Food Programs, and Household Size on Food Consumption

Donald A. West and David W. Price

The availability of food to American households is a continuing public problem. There is concern about adequate amounts of food for households and about the coverage and high costs of food distribution programs. Yet the relationships between food availability and its determinants, including food distribution programs, have not been examined closely. This is partly because major increases in these programs have occurred recently and partly because data on all major sources of food for households have not been available.

Studies by Prais and Houthakker, Friedman, Currie, and others have examined income food expenditure relationships among European and U.S. households. However, these investigations were conducted prior to the implementation of sizable food distribution programs.

Specific questions that have not been fully answered are: How is the value of food consumption affected by receipt of "bonus" food stamps and free lunches?[1] Have the relative impacts of income and household size on food expenditures changed? The purpose of this paper is to examine these questions using a 1972–73 sample of households containing eight- to twelve-year-old children in the state of Washington.

The Sample

The sample consisted of households containing a total of 995 children between the ages of eight and twelve. The sample was stratified by poverty level and ethnic group and contained larger numbers of Blacks and Mexican-Americans than would have been obtained by a random sample of the state's population.[2]

The child is the unit of observation, and the sample generalizes to the socioeconomic background of the child rather than the household. Household size in this sample is larger than a random sample of households of the state would yield for three reasons. First, the household was required to have an eight- to twelve-year-old child, which excluded all one-person and most two-person households. Second, Blacks and Mexican-Americans have larger households than Anglos. Third, the child being the unit of observation gave a higher probability of the larger household being selected. Where siblings were included, the household was assigned a multiple weight.

There are several advantages of this type of sample. The disproportionately larger percentage of households with low incomes provides a larger number of observations at the low income level, while still retaining an adequate percentage (62%) with incomes above 125% of poverty level. All households are at approximately the same stage in the family life cycle, most heads were thirty to fifty years of age, so relationships can be estimated net of the influence of life cycle (see Price 1969).

Forty-nine percent of the sample were Anglos, 26% were Blacks, and 25% were Mexican-Americans (table 1). Thirty-eight percent of the sample were in households with incomes below 125% of the poverty level. Just over one-fourth of the sample were in households receiving food stamps, and more than one-third received free school lunches.

Selection of Variables

The dependent variable in the analysis—value of food consumed—consists of all food items purchased plus food from other sources. Food from other sources includes food purchased with bonus food stamps, free U.S. Department of Agriculture commodities, free school lunches, gifts of food, food produced in gardens or on farms by the house-

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[1] "Bonus" food stamps are defined as the face value of food stamps minus their cost to the recipient.

[2] The entire sample is in essence six different samples each representative of six different strata or populations within the state. These strata are income categories above and below 125% of the poverty level for each of three ethnic groups: Mexican-Americans, Blacks, and Anglos. School districts were stratified by size and geographic area within the state. Probability samples of districts and individual schools were then drawn. Within each school, lists of children in each of the six strata were compiled and random samples were drawn from each list.

Table 1. Descriptive Characteristics of the Sample

	Mexican-Americans n = 245	Blacks n = 256	Whites n = 491	Total Sample n = 992
	Mean			
Total value of food obtained per equivalent adult ($/month)	41.36	45.66	46.25	44.91
	(14.35)[a]	(13.54)	(15.11)	(44.10)
Monthly income ($/month)[b]	156.98	234.82	230.97	214.05
	(82.43)	(140.24)	(126.00)	(125.23)
Household assets ($/month)[b]	2,504.00	4,384.00	4,579.00	4,025.00
	(2,096.00)	(3,718.00)	(4,394.00)	(3,872.00)
Household size (no. of persons)	7.13	5.49	5.32	5.80
	(2.28)	(1.86)	(1.72)	(2.05)
"Bonus" food stamps ($/month)[b]	4.13	4.04	3.64	3.86
	(7.03)	(6.93)	(7.79)	(7.39)
Value of free NSLP lunches ($/month)[b]	3.48	2.78	1.32	2.15
	%			
Percentage with home-produced meat	18.0	28.1	45.8	34.5
Length of pay period				
Week	46.3	14.4	20.6	24.5
Two weeks	16.8	31.6	33.8	29.7
Month	18.4	28.1	19.4	21.5
Percentage receiving food stamps	29.9	28.9	20.8	25.1
Percentage participating in National School Lunch program	88.1	79.3	48.1	66.0
Percentage receiving free school lunches	55.7	43.7	26.4	38.0
Percentage of adult respondents with less than 12 years of education	86.9	27.4	31.0	43.6

[a] Standard deviations in parentheses.
[b] Equivalent adult basis.

hold, and meat obtained through hunting or fishing.[3]

Household income is the sum of annual earnings for all members of the household plus transfer payments (social security, veterans payments, welfare, unemployment compensation, alimony and child support, the value of USDA commodities received, and the value of gifts in the form of cash or commodities). Two components, the value of bonus food stamps and the value of free National School Lunch Program lunches, were specified as separate variables in order to estimate the effects of these programs.[4] Free school lunches were valued at $7 per child per month.[5]

Assets include the total market value of owned property (house, vehicles, and other property) plus liquid assets (checking and savings accounts, bonds, etc). Assets are a source of wealth from which families may borrow for food in periods when current income is inadequate. It should be important among households whose incomes follow seasonal patterns or who incur unusually large expenses. Owned assets permit a household to consume at levels consistent with anticipated "permanent" income in times when "transitory" incomes are low (Friedman, pp. 3–37).

Both household size and the age-sex composition of its members were specified with equivalent adult food scales (Prais and Houthakker, Price 1970). These scales, derived from analysis of household behavior rather than from nutritional standards, assign index values to household food expenditures where the weight for the first adult is 1.0 and then is proportionally less for each other household member.

Equivalent adult scales can also be used to account for economies of size. Using 1965 household survey data, Price estimated scale values that varied according to whether the child was the first, second, third, or fourth child of the household (1970). These values were incorporated with the scales showing age-sex differences to reflect economies of size. These revised scales were used to put household food consumption on an adult equivalent basis.

Conceptually, a weighted average of equivalent adult scales for all commodities would yield an income scale. The authors know of no one who has done this as yet. Instead, an income scale has been estimated by using the concept that differing size households with the same adult equivalent food

[3] Home-produced food was evaluated at the retail, grocery-store prices. Elk and deer meat were evaluated at beef prices.

[4] The USDA commodity distribution program was not analyzed separately, since only a small proportion of the sample received USDA commodities.

[5] The figure of 35¢ per lunch was near the average price 34.3¢ charged for lunches in Washington school districts in the 1970–71 school year (see West and Hoppe, p. 4).

expenditure are equally well off ("Estimating Equivalent Incomes on Budget Costs by Family Type"). This income scale was used in this study to adjust income, assets, bonus food stamps, and the value of free lunches.

The scales account for economies of size and age-sex differences in the sample from which they were estimated. However, they may not adequately specify economies of size that exist among other populations. Consequently, household size as expressed by the number of persons was included as an independent variable in this study to test for the presence of additional economies of size.

Two other variables were included in the model. These were meat produced on farms or obtained by hunting and the length of the pay period for the major income earner. The latter was included to measure the effect of household cash flows on food expenditures.

In the early stages of model development, a number of additional variables were included. These were meals purchased outside the home, ethnic status, female-headed households, education and occupation of household adults, current geographic location, and psychological variables representing need levels and management style. These variables were dropped because the theoretical justification for their inclusion was weak and because they had no significant effect on the value of food consumed.

Analysis

Relationships among the variables were first investigated using the University of Michigan's Automatic Interaction Detector (AID) (Sonquist, Baker, and Morgan). This analysis did not identify any strong interactions among the independent variables. Therefore, a single-regression model was estimated using the entire data set. However, the total unweighted sample does not accurately represent the state's population of households with school-aged children. About 95% of Washington's residents are Anglos, and the Anglo portion of the sample closely represents this population. Consequently, separate regression analyses were run for each ethnic group. This permitted full interaction between ethnicity and the other independent variables. Tests made of the reduction of the error sum of squares showed significant differences exist among the regression coefficients for the three ethnic groups (Johnston).

Income was specified in natural logarithms to account for decreasing rates of increase in food consumption. Household size was also specified in logarithms to capture decreasing economies of size. Application of Bartlett's test to error variances of four regression subsets indicated the presence of heteroscedasticity. The error variances were found to be proportional to the square of the natural log of income; consequently, the data were transformed by multiplying through by the reciprocal of the log of income (Johnston).

Results

Income exerts a significant but relatively small effect on the value of food consumed (table 2). The income elasticity is approximately 0.04. This value is low relative to those estimated in other studies (Reese, Feaster, and Perkins) but is reasonably consistent with the elasticity of 0.1 found for low income households in data from the USDA 1965 Household Food Consumption Survey (Egbert and Hiemstra 1969). By ethnic group the income coefficient is largest for Mexican-Americans, the group whose mean income per equivalent adult is smallest (table 1).

Two possible explanations for the low income elasticity are as follows. First, the range of observations does not include households with very low incomes, where food expenditures may be more responsive to income. The state of Washington has a relatively high Aid to Families and Dependent Children payment, which limits the number of observations at the extremely low end of the income range (Office of Program Planning and Fiscal Management). Second, the specification of the model differs from other studies. The value of food consumed includes food from nonmarket sources, some of which may be less sensitive to income. Additionally, the asset variable, which is correlated with income ($r = 0.52$), may be capturing some of the effect ascribed to income in models that omit assets.

The assets coefficient for the entire sample is significant and has a positive sign. It shows that an additional $10,000 in assets is associated with an increase of approximately $4 in the value of food consumed per month (both variables are on an equivalent adult basis). Other empirical evidence for the asset effect is limited; however, the estimates are consistent with Friedman's permanent income hypothesis and his results (Friedman).[6]

Among the ethnic subgroups, assets are significant only for Anglos (table 2). Mexican-Americans, who have the lowest mean income, have assets that average only about one-half the mean for Anglos (table 1).[7] Their low level of assets may account for the nonsignificant relationship with food consumption. The asset coefficient for Blacks is also nonsignificant, although the mean

[6] Assets, as defined in this study, fall within Friedman's classification of nonhuman wealth. For additional discussion on the theory of how nonhuman wealth protects a planned level of consumption against unexpected occurrences and of how proportional increases in nonhuman wealth and permanent income increase levels of consumption, see Friedman, chapter II, especially pp. 16–17.

[7] If one posits that assets (A) are a function of income (I), that relationship is $A = -25{,}364 + 137.29I + e$, where $A = 0$ at $I = 184.74$ (t-value $= 17.325$).

Table 2. Regression Results: Food Consumption per Month (Equivalent Adult Basis) by Ethnic Group

	Regression Coefficients			
Independent Variables	Mexican-Americans	Blacks	Whites	Total Sample
Constant term	55.496	38.391	48.112	45.473
	(5.252)[a]	(3.196)	(6.762)	(9.140)
Ln monthly income[b]	3.335	2.854	−0.134	1.910
	(2.092)	(1.347)	(0.119)	(2.398)
Assets[b]	0.00010	−0.00020	0.00070	0.00038
	(0.211)	(0.675)	(4.272)	(2.908)
Ln household size	−16.253	−6.774	−4.572	−8.394
	(5.899)	(2.788)	(2.134)	(6.412)
Bonus food stamps[b]	0.610	0.432	0.149	0.297
	(5.087)	(3.399)	(1.758)	(5.054)
Value of free lunches[b]	0.264	0.587	0.785	0.598
	(0.880)	(1.691)	(3.043)	(3.675)
Home-produced meat (dummy)	1.950	4.445	2.671	3.316
	(0.884)	(2.667)	(2.153)	(3.725)
Length of pay period (dummies)				
Week	−1.595	1.600	−1.406	−1.495
	(0.731)	(0.589)	(0.773)	(1.282)
Two weeks	−4.190	−2.845	−0.543	−2.446
	(1.513)	(1.357)	(0.322)	(2.064)
Month	−6.869	−1.368	−2.081	−3.495
	(2.535)	(0.580)	(1.131)	(2.740)
R^2	0.273	0.318	0.268	0.245
Number of observations	245	256	491	992

[a] t-values in parentheses.
[b] Equivalent adult basis.

value of assets among Blacks is nearly as large as that for Anglos. This lack of significance may be due to a smaller proportion of equity in the assets, smaller sample size, and the smaller variance of the asset variable (table 1).

Given our analysis, one can only hypothesize why the asset effect appears stronger among Anglo households. Households with relatively low incomes may derive greater satisfaction from ownership of some minimum level of assets than they do from additional food. Only after this minimum level is attained are additional allocations made for food. This hypothesis requires further investigation, but it lies beyond the scope of this study.

The household size coefficient indicates that the monthly value of food consumed per equivalent adult is reduced by \$2.54 as household size increases by one person. This shows additional economies of size in food procurement and preparation not reflected in the equivalent adult scales used to adjust the data. Reasons why the scales may not control for all economies of size are: (*a*) the model specification in this study differs from the model used to estimate the scales; (*b*) less accurate estimates of size economies may have resulted from the USDA Household Survey data, since only about one-third of the households had six or more members; (*c*) economies of size may have increased over time with the adoption of home freezers and other improvements in food preservation; and (*d*) estimation errors in this study caused by correlation of household size with income and assets.

Among ethnic groups, economies of size were greatest for Mexican-Americans. This may be due to cultural food practices or to economic factors. Earlier work by Price indicates that economies of size vary among food groups (1970). Mexican-Americans may be serving more of the food items where such economies exist.

Bonus food stamps significantly increased the value of food consumed. The coefficient for this variable is interpreted as the propensity to allocate the additional income provided by the bonus stamps to food.[8] The coefficient for the entire sample shows that approximately one-third of the additional income from stamps is used to purchase food. This propensity is below the range of 0.60 to 0.72 estimated by Reese, Feaster, and Perkins for low income families. However, it exceeds the average propensity of 0.21 for all household income allocated to food in this sample. In comparison, the

[8] By law, food stamps can be used only for purchase of food. Bonus stamps (the value of the stamps minus their cost) however "free-up" cash income. The propensity to consume additional food is defined as the proportion of this "freed" income allocated to food.

marginal propensity fo consume food out of total income for the entire sample is about 0.05.[9] The marginal propensity to obtain food out of bonus stamp income (0.30) is still below the average propensity of food stamp recipients to consume out of all income (0.37). This is consistent with economic theory in which bonus stamps are viewed as an addition to income and marginal propensities to consume food are expected to decline as incomes increase.

Substantial differences exist among the food stamp coefficients for the three ethnic groups. Anglo recipients have a low propensity to consume food out of the bonus stamp income while the propensity for Mexican-Americans is highest at 0.61. The difference may be due to the way the ethnic groups view their low income position. If Anglos view their low income as temporary, their food purchases may be planned according to anticipated permanent income and, therefore, be less sensitive to what is viewed as temporary bonus stamp income. If Mexican-Americans, on the other hand, believe their incomes will remain low over time, they would allocate a higher proportion of bonus stamp income to food. The difference in response to bonus stamps is consistent with Anglos' consumption being more responsive to assets (an indicator of permanent income), while that of Mexican-Americans is more responsive to current income.

The free lunch coefficient for the entire sample (0.598) indicates that an additional unit of this subsidy has a greater effect on food consumption than do food stamps. Examination of the ethnic group results shows that the free lunch effect is strongest among Anglos and weakest among Mexican-Americans. One explanation for the relative differences in the free lunch and food stamp effects among ethnic groups may be the attitudes of parents toward the school lunch. Anglo parents may view the free school lunch as largely supplemental to their children's diets and might then allocate the free lunch transfer to additional food. In contrast, Mexican-Americans may believe the free lunch provides a major part of their children's nutritional requirements and might utilize the cash income, otherwise spent for lunches, for nonfood items. A related study based on the same sample shows that the Mexican-American children receive a larger proportion of their daily intake of food from the school lunch than do the Black or Anglo children (Price et al. 1975).

Home-produced meat has a significant impact on the value of food consumed. Estimates for the total sample show the monthly value of food per equivalent adult increased by $3.32 in households that obtained some of their meat from nonmarket sources. Home-produced fruit or vegetables did not significantly affect the value of food consumed.

As Madden and Yoder found, increases in the length of pay period reduced the value of food consumed. The coefficients for the weekly, biweekly, and monthly period estimated with the entire sample are all negative ("other" pay periods is the omitted variable). They become larger in absolute value as the length of the pay period increases. Estimates by ethnic group show the effect of pay period is strongest among Mexican-Americans.

[9] The coefficient for the variables, natural log of income, is 1.910. Evaluated at the mean for this variable, the impact on value of food consumed is 10.249. The same impact can be obtained by attaching a coefficient of 0.04788 to the arithmetic mean for income per equivalent adult ($214.05).

Concluding Remarks

The USDA food stamp and free lunch programs increase the value of food consumed by eligible Washington households. The proportion of the additional purchasing power provided by the programs that is allocated to food exceeds the marginal propensity to consume food out of current income. It is, however, below the average propensity to consume food by low income households. Variation in specific program impacts exists among the ethnic groups. Bonus food stamps have a greater impact on food consumed among Mexican-Americans than among Blacks or Anglos, while the reverse occurs for the free lunch transfer.

The relatively small impact of current income and the significant impact of assets on the value of food consumed have important implications. These results are consistent with Friedman's permanent income hypothesis in which assets are used as an indicator of permanent income. These findings suggest the amount of assets owned should be considered as a criterion in determining eligibility standards for food distribution programs such as food stamps and free school lunches. Economies of household size in food consumption were also found to be substantial. This suggests a sliding scale for household size as a criterion for eligibility in the food delivery programs.

The study supports earlier research that shows that food purchases are inversely affected by the length of the pay period for adults in the household. For policy purposes, adoption of short pay periods and frequent allocations of food stamps in situations where it is desirable to maintain food outlays should be considered.

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The Price Responsiveness of U.S. Corn Yields

James P. Houck and Paul W. Gallagher

Production economics theory shows that the profit-maximizing output of a commodity depends, among other things, upon product and input prices. Supply functions consistent with this theory have been estimated for many agricultural crops both in the United States and elsewhere. However, the biological nature of the production process, the time lags involved between planting and harvest, and the generally extensive use of land and climate leads naturally to the separation of total crop production into acreage and yield components.

Typically, acreage is viewed as the major decision variable with respect to input and output prices. Per acre yields are generally regarded as dependent upon technological trends, weather, and other more or less noneconomic influences. The recent work by Perrin and Heady is a good example of this approach. Only a little literature exists on attempts to measure the price responsiveness of crop yields (Guise, Hee, Krishna), although some recent methodological work can be found (Whitaker). This note concerns the price responsiveness of U.S. corn yields when both output and input prices are considered.

Theoretical Basis

Let the production function for corn be written as

$$(1) \qquad C = f(F, L),$$

where corn output (C) is a function of fertilizer (F) and land (L). Assume other inputs, technology, and environmental influences to be impounded in the function (f).

Suppose that the production decision is made in two stages. First, farmers decide on the amount of land (L_o) to plant to C. Later they decide at what level to fertilize it. The acreage decision may be influenced by expected prices, provisions of various government programs, crop rotation requirements, and other, possibly noneconomic, considerations. Neoclassical production theory based on profit maximization leads to a general supply function, which can be expressed as

$$(2) \qquad C = g(PF/PC, L_o),$$

in which the output (C) is a function of the prices of variable inputs (PF in this case), the output price (PC), and the already decided land input (L_o). The price ratio appears because profit maximization requires that the marginal physical products of variable inputs be equated to input-product price ratios. Thus, the supply function of equation (2) is homogeneous of degree zero in prices.[1] Again, the function g impounds everything else for convenience.

An output-per-acre yield function can be derived from equation (2) as

$$(3) \qquad Y = C/L_o = h(PF/PC, L_o).$$

This function, aggregated over all producers, is the theoretical basis for the empirical study of corn yields and prices that follows. On well-known a priori grounds, we expect the net relation between Y and PF/PC to be negative. Similarly, the net relation between Y and L_o also will be negative if production occurs in the rational area where the marginal product of L is less than its average product (Y in this case).

Estimating Equations and Data

The theoretical development of equation (3) sidesteps several important variables, apart from other inputs, that are crucial to an empirical analysis of time-series data on corn yields. Among them are technological change, government programs, and weather plus other environmental factors. Moreover, the time lag between production decisions and harvest requires special attention to the specification of price, policy, and weather variables.

The following is a general, composite statement of the several corn-yield response equations actually estimated with crop year data over the 1951–71 period (all data used here are from official USDA publications):

$$(4) \quad Y_t = b_o + b_1(PF_{t-1}/PC_{t-1}) + b_2L_t + b_3W_t + b_4D_t + b_5T_t + e_t,$$

where Y is the U.S. corn yield in bushels per harvested acre; PF is the weighted average of USDA fertilizer price indexes (1967 = 100) published in

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[1] If other variable inputs had been included specifically, equation (2) would exhibit their prices relative to P as additional determinants of Y.

September, December, March, April, and June;[2] PC is the average price received by farmers for corn in dollars per bushel; L is harvested acreage of corn in millions; W is the weather in the growing season—the proxy variable used is the USDA index of average pasture moisture conditions in five midwestern states (Illinois, Indiana, Ohio, Iowa, and Nebraska) in percentage of normal during the growing season; D is one or more zero-one variables reflecting acreage restrictions on corn and the 1970 corn blight experience; T is the technology trend value, 1951 = 1, 1952 = 2, etc.; e is a random, serially independent, mean-zero variable with finite variance assumed to reflect the net impact of all unspecified variables influencing Y_t; and t is a subscript indexing the crop year.

For this analysis, the production function for corn, whatever its true form, is assumed to generate yield functions that are approximately linear in price ratios and other variables over the relevant range. The earlier assumption that acreage (L_t) is determined in advance of yield (Y_t) is carried over to the empirical analysis.

Numerous versions of the general expression in equation (4) were estimated by ordinary least squares (OLS) in preliminary analyses. In particular, corn acreage was added and dropped, the weather proxy was used with both current and lagged values, a zero-one policy variable was investigated, and technology was reflected by a linear trend in some versions and by a logarithmic trend in others.

Data more recent than the 1971 crop were not used because the particular weather proxy (W) was not available from USDA after that crop year. Since this research effort focused on price effects and not upon the isolation and measurement of weather impacts, alternative proxies were not sought out. However, further and more refined work along these lines will require other measures for weather effects.

Of course, alternative specifications of the price variables as well as the other variables are clearly possible. The single-period lag on the corn price, for example, implies the simplest sort of price expectation formation. Similarly, the fertilizer price data is an aggregate index averaged over the previous crop year; it also might be sharpened considerably.

Major Results

Four of the estimated equations are summarized in table 1. Equation (1.4) was used in figure 1 to illustrate the behavior of actual versus estimated corn yields over the data period. These equations are representative of the array of results obtained, especially insofar as the fertilizer-corn price ratio is concerned. They provide clear evidence of price responsiveness in corn yields.

Although the results are nearly self-explanatory, a few comments are appropriate. For about half of the data period, corn production was strongly affected by a variety of voluntary acreage control programs applied by the federal government (Houck and Ryan). The programs affected acreage directly and yields indirectly. Consequently, statistical estimates also were calculated when corn acreage, L_t in equation (4), was replaced by a zero-one variable ($D61$) to reflect the acreage-controlling policy regime, equations (1.2) and (1.4). The significant positive coefficients estimated for this variable confirm the yield-increasing tendencies of programs seeking output reduction via land constraints. Using both L_t and $D61$ in the same estimating equation did not produce acceptable results. The serious negative impact of the unusual 1970

[2] Each reported fertilizer price index observation was weighted by the proportion of the crop year to which it applies. The reporting month was considered as the midpoint of the individual period and the observation itself representative of the entire period.

Table 1. Regressions with Corn Yield as Dependent Variable

	Constant	PF_{t-1}/PC_{t-1}	L_t	$D61$	$D70$	W_t	W_{t-1}	T	LNT	$\bar{R}^2$	Durbin-Watson
(1.1) Coefficient	28.427	−0.2133	−0.3073		−16.806	0.1044	0.3433	2.686		0.985	3.06
t-value	2.52	3.59	2.57		7.07	1.01	3.29	22.18			
Elasticity		−0.283[a]									
(1.2) Coefficient	9.930	−0.1813		4.397	−15.531	0.1802	0.2150	2.574		0.986	2.65
t-value	1.04	3.11		2.31	6.33	1.65	2.10	15.33			
Elasticity		−0.244[a]									
(1.3) Coefficient	−47.739	−0.5698	−0.4414		−17.327	0.2990	0.5514		41.824	0.971	2.00
t-value	2.67	6.33	2.76		5.30	2.09	3.87		15.97		
Elasticity		−0.756[a]									
(1.4) Coefficient	−66.310	−0.5101		7.675	−15.287	0.4019	0.3525		38.093	0.980	2.12
t-value	5.34	6.32		3.67	5.24	3.09	2.83		12.72		
Elasticity		−0.687[a]									

Note: Variable definitions: see text; in addition, $D61$ = 0 in 1951–60 and 1 in 1961–71; $D70$ = 1 in 1970 and 0 otherwise; and LNT = natural log of T.

[a] Elasticity with respect to PF, calculated at data means.

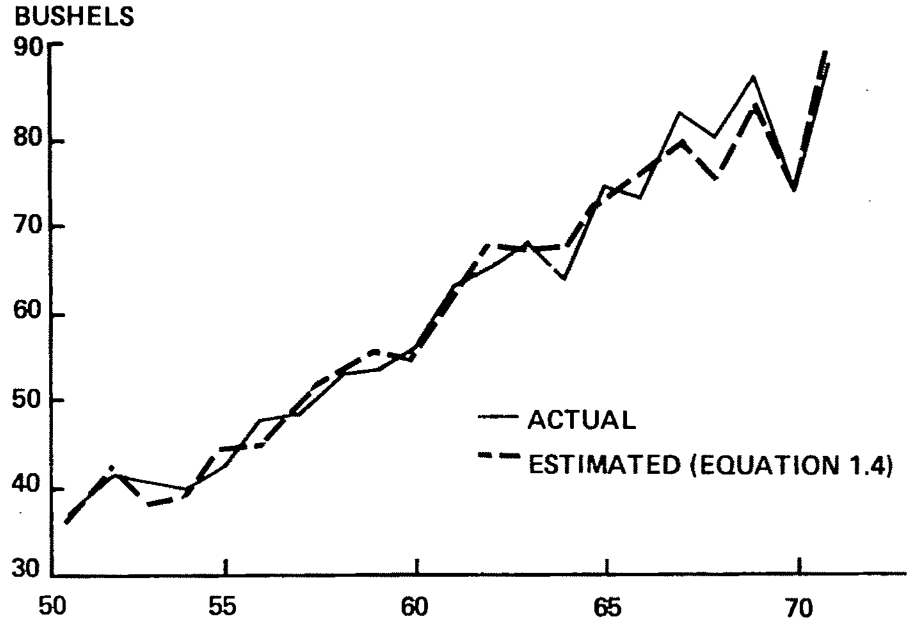

Figure 1. U.S. corn yield per harvested acre

corn blight was removed from the analysis by means of *D70*. Incidentally, the estimated 15.3 to 17.3 bushels per acre net impact of the blight is consistent with most agronomic measurements of that phenomenon.

The weather proxy (*W*) used here is imperfect, but it does provide generally sensible results. The consistently positive lagged effect of W_{t-1} presumably shows the net impact on yield contributed by carryover from the previous year's soil moisture.

The linear and log trend variables are meant to account for the yield-increasing effects of mechanical and biological technical change. The log trend is appealing for corn because it increases at a declining rate over the data period.[3] For instance, in the early 1950s, the log trend and its coefficient account for annual yield increases on the order of 6 to 9 bushels per acre. By 1970–71, this annual trend effect was only about 1.5 bushels per acre.

The coefficients on the price ratios display *t*-values that are relatively large. They suggest statistical significance at levels beyond the 99% confidence range. The larger estimated price ratio coefficients seem to be the most significant and occur in the two equations featuring the log trend, (1.3) and (1.4). It is clear that significant net price response is present in corn yields.[4] This is quite reasonable with a highly fertilizer-responsive crop like corn. Extensive analyses using other variable input prices, individually or in groups, were not attempted.

These estimates were computed for an era in which neither fertilizer nor corn prices were as volatile as in more recent years. Still, they do suggest that the relative price of fertilizer has exerted a measurable influence on corn yields apart from weather, trend, and government acreage programs. The yield consequences of future fluctuations in relative fertilizer prices, should they occur, could at least be approximated with these elasticities.

Implications for Supply Elasticity

Because production is acreage multiplied by yield, total supply elasticity is the sum of the acreage response and yield response elasticities with respect to product prices (Allen, p. 253). Some recent estimates of the short-run acreage response for corn (with respect to a one-year lagged price) imply quite low acreage elasticities in the neighborhood of 0.1 to 0.3 (Houck and Ryan, Ryan and Abel, Houck et al.).

The negative price elasticities shown in table 1 refer to isolated changes in fertilizer prices relative to corn prices. Because the two prices enter the estimating equation in ratio form, the yield elasticity of an isolated change in corn prices relative to fertilizer prices is the same value except that the sign is positive.[5] Hence, yield elasticities with re-

[3] The origin of the log trend was moved back to 1946 to give softer curvature to the trend at the beginning of the data period. The extent of this adjustment was arbitrary but suggested by examination of indexes for quantities of farm machinery and other nonfarm inputs used in the Midwest.

[4] One might reasonably argue that among the independent variables in this analysis the weather proxy (*W*) is the most likely to exhibit measurement error, especially in its relation to corn production (Johnston, p. 282). This line of reasoning leads to the conclusion that estimated price ratio coefficients are asymptotically biased toward values absolutely smaller than the true parameters and therefore strengthens the argument that sizeable price response exists.

[5] This can be shown by looking at the following simplified

spect to corn prices are in the neighborhood of 0.24 to 0.76.[6]

These results, although not fully comparable in underlying data and methods with previous acreage response studies, do provide solid evidence that taking acreage response estimates as approximations to total supply elasticities is to seriously underestimate the price responsiveness of corn production when fertilizer price is held constant. Rather than a short-run supply elasticity of less than 0.3 with regard to its price, corn may actually have a total supply elasticity as high as 1.0, other things held constant. In any case, analyses of corn production changes in response to price changes, either from the market or induced by government policy, should explicitly take into account the relation between corn and fertilizer prices faced by farmers and its effect on per acre yields.

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equations: $Y = a - b(PF/PC)$; then $\partial Y/\partial PF = -b(1/PC)$, and the elasticity with respect to PF is $(\partial Y/\partial PF)(PF/Y) = -b(PF/PC)(1/Y)$. On the other hand, $\partial Y/\partial PC = b(PF/PC^2)$, and corresponding elasticity is $\partial Y/\partial PC(PC/Y) = b(PF/PC)(1/Y)$. So the two elasticities are identical except for sign.

[6] The analyses also were run with the corn-fertilizer price ratio as an independent variable. The estimates were as statistically significant as those in table 1 and identical up to two significant digits.

Market Performance in the U.S. Vegetable Oil Industry: An Application of Simulation for Market Analysis

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Studies of market performance in agriculture have traditionally concentrated on the farm and retailing aspects of the marketing process, since price and cost data are generally available for farm and retail markets. This is not usually the case for food processing industries, however. Firm cost data are seldom made available voluntarily by food processing companies, and even price lists are difficult to obtain. These constraints have limited the extent to which studies have been able to adequately assess market performance in food processing industries.

The purpose of this note is to discuss the use of simulation as a tool for market performance analysis. A specific application is made to the processing sector of the domestic vegetable oil industry, a highly concentrated sector for which price and cost data are not readily available. Using representative plant and firm models, returns on five products are estimated over time by simulating production and marketing functions at actual input and output prices by months for the period January 1974 through December 1975. The results indicate that market power in the vegetable oil industry was insufficient to generate excessively high returns over this period and demonstrate the potential of the simulation approach for use in studies of market performance.

Foundations of the Analysis

Five measures or conceptual approaches have been applied to market performance analysis when price and cost data are not available. These are productivity measures, marketing bill measures, flow analysis, market structure measures, and the application of welfare economics (Marion and Handy). The measure of market performance used in this study, the market rate of return, is a consequence of recent efforts by the Economic Research Service to identify the cost and profit components of the marketing margin for different food products and is an outgrowth of marketing bill measures. The market rate of return, considered in the proper framework, "lies at the heart" of the analysis of market performance (Caves, p. 101). In this respect the rate of return, when it can be determined, serves as a far better measure of market performance than any of the other measures or conceptual approaches that have been applied to market performance analysis.

Recently, Griffin proposed the use of the process analysis approach for determining empirical industry cost curves on the basis of a representative industry firm (1972, 1974). In this study simulation is substituted for process analysis in a similar procedure for determining empirical industry cost curves. Marshallian representative firms are taken as the basis of the analysis, with the estimated rates of return for the products of the representative firm being taken as approximations of the rates of return on the same industry products. The points of reference to which the rate of return applies in this study then are the product markets in which the representative firm participates, not the aggregate rate of return to the representative firm itself.

Three representative firms and six representative plants were identified in the processing sector of the U.S. vegetable oil industry for this study. These six plants included a soybean processing plant, a vegetable oil refining plant, a cooking oil bottling plant, a margarine manufacturing plant, a shortening canning plant, and a mayonnaise manufacturing plant. Of the three Marshallian representative firms, the first was defined to include soybean processing as its primary function, the second to include vegetable oil refining, cooking oil bottling, margarine manufacturing, and shortening canning as its primary functions, and the third firm was defined to include mayonnaise manufacturing as its primary function.

The System Model

The six-plant, three-firm system simulation model of the processing sector of the domestic vegetable oil industry was constructed by specifying the technical parameters of representative stage, plant, and firm production functions item by item. Representative stages, plants, and firms were selected on the basis of plant visitations and communications with individuals knowledgeable on the industry structure. The traditional economic engineering ap-

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proach (French, Sammet, and Bressler) was used in the specification and actual measurement of linear non-substitutable production functions. Information for specifying the levels of the technical parameters for the production functions was obtained by collecting data during visits to over forty plants and firms in the industry, by utilizing census data on plant specifications, and by consulting with equipment manufacturers. The entire system model was constructed to be jointly interactive so that all model plants and firms could be operated simultaneously within the simulation framework. If all technical parameters of each plant and firm are specified correctly, then the complete system simulation model should be representative, since by definition it is composed of representative production stages, plants, and firms.

Each of the three firms included in the simulation model were assumed to be spatially separated. Hence, transportation costs were incurred in shipping crude soybean oil from the soybean processing firm's plant to the second model firm's vegetable oil refining plant and in the shipping of refined vegetable oil to the third model firm's mayonnaise manufacturing plant. The vegetable oil refining plant, the cooking oil bottling plant, the magarine manufacturing plant, and the shortening canning plant, all operated by the second model firm, were assumed to be located at the same site. All assumptions concerning spatial location reflect prevalent industry patterns.

The results of a simulation experiment cannot be considered valid unless the underlying model is verified as accurate. Two methods were used to verify the accuracy of the model constructed for this study. First, actual plant and firm input and output data were used to check for inconsistencies in the generated input and output levels of the model plants and firms. No gross inconsistencies were found between actual industry input and output statistics and those generated by the model using this method. Second, the system simulation model was used to generate average costs for producing different industry products using 1975 prices. These generated average costs were then compared with available industry accounting average costs to check for inconsistencies. This comparison yielded certain discrepancies between actual industry accounting costs and average costs generated by the model.

For the cost verification method, detailed accounting data were available from industry sources on firm costs for three types of products. These were crude soybean oil, refined vegetable oil, and pint jars of mayonnaise. With respect to crude soybean oil, the cost of producing 1 pound of oil was estimated by the model to be 1.5¢, while an average of data for thirteen processing firms in the industry indicated an average cost of 1.8¢ per pound in 1975. To some degree the discrepancy between these figures is attributable to the inclusion of older, more labor-intensive plants in the composition of the firm accounting data. With respect to vegetable oil products, the costs of producing a refined vegetable oil, a margarine base oil, and a shortening base oil were estimated by the simulation model to be 1.2¢, 2.3¢, and 2.8¢ per pound of oil, respectively. The corresponding figures for similar but not identical products, as reported by one firm in the industry, were 1.0¢, 1.7¢, and 2.4¢. Again, the discrepancies can be accounted for by differences between the firm for which costs were reported and the simulated model firm—the industry firm's plant was considerably more modern than the model firm's plant. Finally, with respect to mayonnaise, the cost of producing pint jars of mayonnaise was estimated by the simulation model to be 23.6¢. Data from one firm in the industry indicated the cost of producing mayonnaise as 22.5¢ per pint. Also, in this case the discrepancy is attributable to variations between the structure of the model firm and the industry firm.

The attempts to verify the accuracy of the simulation model indicate that, when allowances are made for discrepancies, the model cost estimates are not greatly inconsistent with available industry data. Although accounting data could not be obtained to verify the accuracy of simulated costs of production for all the products considered in this study, each of the simulation plant and firm models were constructed using the same technique. Hence, any biases that exist in the estimation of costs for one product are likely to exist in similar degrees in the estimation of costs for other products.

A Multiple Period Simulation Experiment

To evaluate the economic properties of the model and to generate descriptive statistics to analyze market performance in the vegetable oil industry, a complete system simulation was performed on a month-by-month basis using data for the twenty-four-month period January 1974 to December 1975. One hundred and four monthly prices for inputs and outputs were collected for each of the twenty-four months in an attempt to re-create the actual environment in which plants and firms in the industry were operating over the period. The stochastic variables in the model were adjusted to remain at their mean levels so that random variations in plant performance would not affect costs or rates of return in any one period.

The simulation was performed so that at the end of each monthly period complete production cost data were generated for five final products of the vegetable oil industry on a per unit basis. These five products were 24 ounce bottles of cooking oil, 38 ounce bottles of cooking oil, pound packages of margarine, 3 pound cans of shortening, and pint jars of mayonnaise. Cost data were generated by components consistent with those used by the ERS.

For each of the five products forty-two separate components were identified for each of twenty-four periods, giving estimates of more than 5,000 separate cost elements.

In order to focus on the key results of the simulation, estimates of the rate of return for the five finished products considered are presented in table 1. The rate of return is defined as the per unit profit after taxes divided by the per unit value of assets. The information presented in table 1 reveals that the variation in profit over the twenty-four-month period was substantial for all five products. In addition, it is apparent that with the exception of margarine profits were generally greater for each of the five final products in 1975 than in 1974. This result contrasts with the fact that soybean prices and rates of return to soybean processors were considerably higher in 1974 than in 1975. These findings indicate clearly that with the exception of margarine finished product manufacturers were able to maintain and improve their rates of return as raw materials prices declined in 1975.

Market Power in the Vegetable Oil Industry

For every product market there is some socially optimal normal rate of return on equity that must prevail if resource allocation is to be efficient (Caves). Although there is a problem in ascertaining what exactly a normal rate of return on equity is, this does not constrain the comparison of relative rates of return for analytical purposes. In specific cases where a detailed study over a period of time indicates that the rate of return in one market is consistently greater than the rate of return in other similar markets and that the rate of return is substantially greater than any long-term interest rate realized over the period, then there is evidence of market power.

Referring to the information presented in table 1, it is readily apparent that the rate of return on cooking oil is substantially greater than the rates of return on the other products considered in this study. The mean rates of return for each of the five products are 0.0982 for 24 ounce bottles of cooking oil, 0.0856 for 38 ounce bottles of cooking oil, 0.0436 for pound packages of margarine, 0.0564 for 3 pound cans of shortening, and 0.0668 for pint jars of mayonnaise. The rate of return on 24 ounce bottles of cooking oil, the product with the highest rate of return, is more than twice the rate of return on margarine, the product with the lowest rate of return. Although a twenty-four-month period is probably not a "long run," it is useful to compare alternative investment opportunities available to firms in the industry over this period with their

Table 1. Profit as a Percentage of Net Worth for Five Products of the Vegetable Oil Industry

Year and Month	24 Ounce Bottles of Cooking Oil	38 Ounce Bottles of Cooking Oil	Pound Packages of Margarine	3 Pound Cans of Shortening	Pint Jars of Mayonnaise
1974					
January	0.0494	0.0504	0.0461	0.0524	0.0184
February	0.0481	0.0287	0.0257	−0.0601	−0.0627
March	0.1005	0.0869	0.0294	0.0436	0.0067
April	0.1074	0.0924	0.1118	0.0642	0.0463
May	0.0752	0.0712	0.0800	0.0482	0.0439
June	0.0654	0.0395	0.0534	0.0105	0.0356
July	0.0735	0.0363	0.0137	−0.0960	0.0035
August	0.0726	0.0421	0.0647	0.0180	−0.0048
September	0.0779	0.0827	0.0286	0.0266	0.0443
October	0.0618	0.0365	0.0409	0.0491	0.0448
November	0.0749	0.0653	0.0476	0.0333	0.0512
December	0.0879	0.0787	0.0313	0.0523	0.0740
1975					
January	0.1288	0.1208	0.0552	0.0994	0.1127
February	0.1495	0.1414	0.0640	0.1205	0.1316
March	0.1336	0.1250	0.0561	0.1012	0.1182
April	0.1370	0.1282	0.0875	0.1104	0.1192
May	0.1467	0.1369	0.1142	0.1323	0.1377
June	0.1396	0.1297	0.1134	0.1254	0.1318
July	0.0861	0.0749	0.0391	0.0455	0.0742
August	0.0708	0.0590	−0.0417	0.0333	0.0625
September	0.0905	0.0791	−0.0361	0.0607	0.0807
October	0.1122	0.1012	0.0045	0.0786	0.1011
November	0.1365	0.1260	0.0112	0.1053	0.1126
December	0.1331	0.1216	0.0078	0.0994	0.1213
Mean	0.0982	0.0856	0.0436	0.0564	0.0668
Standard deviation	0.0326	0.0363	0.0408	0.0547	0.0521

actual rates of return. The rate of return on corporate triple A bonds averaged 0.0871 from January 1974 to December 1975. For purposes of argument, if this figure is taken as the opportunity cost of investment, then of the five product markets considered there were extra-normal rates of return over the period only for 24 ounce bottles of cooking oil. There were apparent inefficiencies in capital equity distribution in the processing sector of the domestic vegetable oil industry over the two-year period. These findings imply the virtual absence of any large degree of market power in the domestic vegetable oil industry during this period. Only in the case of 24 ounce bottles of cooking oil were there indications of some degree of market power.

Two arguments may be offered to explain the absence of a large degree of market power in the processing sector of the domestic vegetable oil industry, even though the sector is highly concentrated. First, and perhaps most important, is the fact that the vegetable oil industry is a nondurable goods industry. It is difficult, if not impossible, to establish the price stability necessary to sustain oligopoly within nondurable goods industries. Traditionally, oligopoly has been identified principally in durable products industries where prices can be maintained by varying inventories and order backlogs (Scherer). In the vegetable oil industry inventories must be limited because of the relatively short life of the product. Hence, prices are difficult to maintain as raw materials costs vary. For this reason the development of a large degree of market power in a multifirm food processing industry would not be expected à priori. Second, a number of potential competitors do not face large entry barriers. For example, in the cooking oil industry there are three major firms that dominate the market. But there are also several that produce private label cooking oil. These potential competitors would only have to place a different label on their product and overcome advertising barriers in order to enter. For the other products considered in this study the situation is similar—there are several potential competitors.

Within the vegetable oil industry the estimation of a mean rate of return for each product allows for a comparison of relative market power. A related measure of market power is the standard deviation of the rate of return. Since market power implies some degree of control over prices and profit by the firm, the temporal standard deviation of the rate of return is likely to be smaller the greater the degree of market power. The acceptance of this premise would imply the expectation of an inverse relationship between the mean rate of return and the standard deviation of the rate of return. Reference to table 1 indicates that except for margarine the results generated by the simulation are consistent with this hypothesis. Twenty-four ounce bottles of cooking oil have the highest mean rate of return and the lowest standard deviation. The implication then is that of the five product markets considered in this study, market power is greatest in the market for 24 ounce bottles of cooking oil and the least for 3 pound cans of shortening.

Conclusion

The results indicate little evidence of market power in the industry, even though most of the product markets of the industry are highly concentrated. This finding implies that some caution is in order when antitrust activities are urged against food processing companies when only data on market structure are available (Dahl, Hoffman, Walters). Each individual case should be considered with respect to the market rate of return and other relevant factors. In the processing sector of the domestic vegetable oil industry there is evidence to indicate that complete economies of scale have yet to be realized in some instances (Lamm, Lamm and Johnson). An arbitrary policy requiring more diversification in the vegetable oil industry might do more harm than good since the implementation of such a policy would prevent the attainment of full scale economies.

The use of simulation, as suggested in this paper, offers a viable and powerful method for evaluating market performance when industry accounting cost data are not readily available. The advantages of using the simulation approach are that it allows for the segregation of individual product markets from aggregates and for the use of explicit measures of market performance, measures that are more precise than the vague and sometimes misleading market structure measures frequently used. The only alternative that also has similar advantages is the use of accounting data. Since accounting data are generally not available for food processing industries and would present some classification and collection problems even if they were available, the simulation approach outlined here offers perhaps the best alternative available for detailed market performance analysis.

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Estimating Optimum Size of Food Processing Plants Using Survivor Analysis

Sheldon W. Williams and James W. Gruebele

As applied to manufacturing plants, optimum size commonly refers to the range in volume over which average total costs, as depicted by the industry's long-run planning curve, are at a minimum (Bain). Knowledge of the limits to optimum size can guide managers in adapting operations to changing conditions. Government administrators and legislators also need that information in framing antitrust policies and in developing legislation to control conduct.

The purpose of this analysis is to appraise the potential usefulness of the survivor technique as an indicator of optimum size. The appraisal considers how trends in industry production and deficiencies in the data may affect the findings of survivor analysis and examines its use in policy formation.

Methods of Estimating Optimum Size

Various procedures have been used to determine optimum size. These include economic-engineering studies (French, Sammet, and Bressler), cost studies of existing plants (Pratten and Dean), and survivor analysis (Stigler, Saving). Markov chain analysis also has been used to project the future size distribution of plants, and thus indirectly to indicate optimum size (Judge and Swanson).

Engineering studies are comparatively expensive (French, Sammet, and Bressler) and may not take into account all factors in the environment in which plants operate (Saving, Sosnick). Heterogeneity of products and of operating conditions, differences in age and in the basis of valuation of physical assets, the operation of many plants at below their optimum volumes, and other problems make it impractical to determine the dimensions of the industry's long-run planning curve by plant cost surveys (Smith, Johnston). Markov chain analysis requires knowledge of what happened to each plant from period to period (Judge and Swanson). Moreover, Markov analysis commonly has been based upon the rather restrictive assumption that transition probabilities remain constant over time. Although Hallberg has suggested a modification to provide more reliable results, the need for this modification complicates use of the Markov technique.

The survivor technique, by comparison, is a relatively simple means of estimating optimum size. As described by Stigler, it rests upon the hypothesis that "the competition of different sizes of firms (or plants) sifts out the more efficient enterprises" (p. 73). It involves classifying the firms or plants of an industry by size and computing the share of industry output for each class over time. If the proportion of industry output by firms or plants of a specified size is maintained or increased, firms or plants of that size are presumed to be of optimum size.[1]

Survival of some firms may be influenced by their ability to exercise market power, to exploit monopsonistic positions in local labor markets, to use inexpensive family labor, or even to circumvent the law. For reasons such as these, survivor analysis may be more suitably applied to determination of optimum size of plants than of firms (Weiss, Mead).

Data Used

This application of survivor analysis is based upon information about the numbers of dairy manufacturing units, by size groups, reported in four USDA publications (Cowden and Trelogan; USDA 1959a, 1965a, 1974). The data originate in reports of production by firms that manufacture dairy products to the Statistical Reporting Service (SRS).

SRS reports production and numbers of manufacturing units separately for each type of product. In this analysis each unit manufacturing a product is treated as a "plant." This procedure, to which there is no feasible alternative, disregards the fact that two or more manufactured dairy products are produced in some plants and that certain manufactured products are produced, in some cases in relatively small volumes, in plants primarily devoted to processing fluid milk. The analysis thus involves manufacturing operations that range from spe-

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[1] Size should be measured by physical volume of output. In industries that are replacing labor with equipment, use of number of employees as an indicator of size may lead to confusing if not misleading results.

cialized single-product plants to parts of multiproduct operations. In 1961 the bulk of the production of butter and nonfat dry milk was in butter-powder plants and of American cheese and evaporated milk was in specialized plants (Williams et al.). However, it is impossible to assess in our data either the degree of plant specialization or the type and extent of its relationship, if any, to average volume per plant and to survival.

Ranges in Optimum Size

Optimum size was estimated for eight dairy manufacturing industries for periods for which data were available (table 1).[2] Upper limits to optimum size were not evident in any of those industries. In all except two, minimum optimum size increased. The two exceptions were nonfat dry milk, for which minimum optimum size was unchanged between 1963 and 1972, and evaporated milk, for which it declined.

Technological developments in production and changes in factor prices evidently were major factors in the changes in minimum optimum size. Between 1958 and 1972 weekly wages of dairy plant workers increased 83%, while prices of machinery and equipment increased 32% (U.S. Dep. of Labor, 1972a, b; 1973; 1975).[3] During that period, the average quantity of whole and skim milk equivalent manufactured per production worker increased 35% (U.S. Dep. of Labor, 1972a, b; 1973; USDA, annual, 1958–72), probably mainly as a result of increased mechanization. Nevertheless, it may be hypothesized that dissimilar trends in demand—here examined using production data—are a factor in the differing trends among industries in minimum optimum size (Stigler).

If the eight dairy manufacturing industries are ranked by percentage increase in production between 1963 and 1972, nonfat dry milk and evaporated milk, in which there were substantial decreases, are at the bottom of the array (table 2). While minimum optimum size did not increase in those two industries, among the others there was no apparent relationship between percentage changes in production and in minimum optimum size. In the butter industry, in which production also decreased, the percentage increase in minimum optimum size was larger than that in three of the five industries in which production increased.

On the other hand, the nonfat dry milk, evaporated milk, and butter industries, in which production declined, were the only industries in which plants that were of minimum optimum size in 1963 decreased in number between then and 1972. Increases in average size of plant also were less for evaporated milk and nonfat dry milk than for the industries with either increases or else smaller decreases in output. These limited observations suggest that an important decline in production may halt or reverse an upward trend in minimum optimum size and force out of production more than the usual proportion of an industry's larger plants.

But sharply declining production was not necessarily the only reason minimum optimum size did not increase in the nonfat dry milk and evaporated milk industries. Both industries involve comparatively large investments in specialized equipment, which may retard exits. Moreover, most nonfat dry milk plants were established during or since World War II. Apparently, new labor-saving technology has not recently been introduced into that industry to the extent that it has in the manufacture of cheese and butter.

Table 1. Minimum Optimum Sizes of Dairy Plants as Determined by Survivor Analysis

Industry	Minimum Optimum Plant Size		
	1957	1963	1972
	--- Million Pounds or Gallons per Year[a] ---		
American cheese	0.75	1.5	3.0
Swiss cheese	—	0.5	3.0[b]
Italian cheese	—	1.0	3.0
Creamed cottage cheese	—	2.0	4.0
Creamery butter	1.0	2.0	5.0
Nonfat dry milk[c]	—	10.0	10.0[b]
Evaporated, condensed whole milk (case goods)	—	55.0[b]	45.0[b]
Frozen dairy products	—	1.0	2.0

[a] All products except frozen dairy products in million pounds.
[b] Proportion of industry output in one or two groups of smaller plants increased slightly but not significantly; changes in other groups supported the estimate of optimum size shown.
[c] Spray and roller, for human food.

Limitations

Several factors may affect the reliability of the findings of survivor analysis. One is lags in adjustment. In each dairy manufacturing industry in which recent economic-engineering studies have been made (American cheese, butter, and nonfat dry milk), minimum optimum size in 1972 as determined by survivor analysis was considerably smaller than the volume at which minimum average

[2] The analysis involved adjusting 1944 data to the slightly different class intervals used in the later data. In all cheese and butter industries, the top open-end groups in 1963—and in creamed cottage cheese also in 1957—were subdivided to permit more detailed comparisons of changes between that and later years. This was done by making successive estimates until all possible distributions were considered that satisfied three constraints: number of plants, total production, and expected shape of the frequency curve. These constraints closely limited the number of acceptable estimates, all of which were taken into account in determining changes in optimum size.

[3] 1958 was the first year for which the indicated data were available.

Table 2. Dairy Industries' Production and Plant Sizes in 1972

Industry	Total Production	Plant Size: Minimum Optimum	Plant Size: Average	Number of Plants: Below Optimum Size in 1963	Number of Plants: Of Optimum Size in 1963	Number of Plants: All Plants
	Value in 1972 in Percentage of Value in 1963					
Italian cheese	266	300	246	79	172	108
American cheese	148	200	224	46	137	66
Swiss cheese	148	600	259	38	103	57
Creamed cottage cheese	127	200	285	36	129	44
Frozen dairy products	107	200	182	54	106	59
Creamery butter	78	250	216	32	55	36
Evaporated milk	60	82	109[a]	56[a]	67[a]	57[a]
Nonfat dry milk	58	100	131	39	75	44

Sources: USDA, annual, 1964, 1965b; 1965a; 1974.
[a] Perhaps slightly distorted by inclusion of sweetened condensed (case goods) in 1972 with corresponding adjustment not feasible in 1963 data; conclusions unaffected.

costs are shown on that industry's long-run planning curve in the pertinent economic-engineering study (Lilwall and Hammond, Nolte and Koller). For various reasons results of the two types of analysis are not expected to be the same. But in industries in which plant size is increasing, economic-engineering studies would be expected to suggest the direction of future changes in minimum optimum size as determined by survivor analysis. Consequently, it may be hypothesized that the smaller volumes shown by survivor analysis are due in part to lags in adjusting plant size to changing conditions.[4]

The process of replacing or modernizing facilities takes time. Consequently, in dynamic industries survivor analysis can be expected to reflect a lag until the industry fully adjusts to changed conditions. Such a lag may continue for some time if plants are operating in the relatively flat portion of the industry's long-run planning curve.

However, not all of the difference in minimum optimum size between survivor analysis and economic-engineering studies should be attributed to a lag. After a period of rising prices for equipment and buildings, lower levels of capitalization could help to account for the continuing competitiveness of moderately large plants built before the rise in prices. These and plants whose assets have been largely depreciated would have lower fixed costs than plants of similar capacity constructed at recent price levels. Moreover some manufacturing operations of sizes below that at which economic-engineering studies show minimum costs may continue to compete effectively because they have advantages in hiring labor, in special outlets for their products, or in other respects not taken into account in economic-engineering studies.

Several characteristics of the available data also may affect the findings of survivor analysis. Very wide group intervals reduce precision. This effect is intensified if there is a wide open-end group at the top of the distribution, particularly if total production of plants in that group is not reported.

Analysis is most practical in industries composed of large numbers of plants. Narrow group intervals in a distribution of a limited number of plants may confuse trends in minimum optimum size. It may be possible to mitigate this problem by combining groups. Whatever the characteristics of the frequency distribution, it is highly desirable that, except for the specification of new intervals at the top of the distribution as plants become larger, group intervals be uniform in all reports.

More specific conclusions might be drawn if numbers of plants by size groups could be determined at relatively frequent and uniform time intervals. In industries in which optimum plant size is increasing, the additional data might provide insights as to when and for how long various intermediate size categories were in the range of optimum size. Unlike the bulk of our findings, it might suggest that under some conditions the upward trend in optimum size is not a steadily progressive phenomenon without reversals.

Obviously, the more specialized the plants in the industry, the more likely it is that the apparent trends in optimum size reflect efficiencies in production of relatively homogeneous products. If plants are not specialized, trends may be influenced by factors associated with the production of different or changing product mixes. Limitations of our data in this respect have been noted.

A high level of profits might distort findings. Mead pointed out that in the Douglas Fir milling industry survivor analysis in the period 1941–51 would have been meaningless because the industry was so profitable that all but the completely inept could survive. There is no indication that such con-

[4] The extent of an apparent lag may be affected by the characteristics of the data.

ditions existed in any of the dairy manufacturing industries during substantial portions of the periods analyzed.

Policy Implications

Survivor analysis is potentially useful as a guide to firm policy. Information it provides can suggest whether plants have sufficient volume to compete effectively, needed volumes of raw material, and the like. Although based on past experience, findings of survivor analysis may also point out the direction of future changes.

In using the survivor technique, management needs to be alert to any limitations in the basic data or in the measure of size employed—and to ways in which those limitations, or a lag in adjustments, may influence findings. In the dairy manufacturing industries, factors such as price supports or difficulties in exiting may retard adjustments. On the other hand the trend to fewer and larger firms and to multiplant operations may expedite adjustments through changes such as greater flexibility in plant operations.

Since antitrust and trade policies are more concerned with firms than with plants, survivor analysis of plants will not provide as good a basis for those policies as will analyses of changes in firms, using either the survivor or the Markov technique. Nevertheless, many firms operate single plants and, with the reservations that have been noted, survivor analysis of plants indicates minimum optimum size for such firms. From it inferences may be made about relationships between competitiveness and market power, about the effects of structural changes on single-plant firms, and about needs for further research.

The bounds of optimum size shown by survivor analysis are influenced by all conditions affecting plant operations, external as well as internal. Moreover, this method of determining optimum size is simpler and much less demanding in its data requirements than alternative methods. Consequently, it offers potential advantages in terms of feasibility and cost as well as of responsiveness to influences not considered by economic-engineering and accounting studies.

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Returns to Scale in Farming: Further Evidence

Irving Hoch

Over the past two decades, a number of studies have applied analysis of covariance to combined time-series and cross-section data in estimating agricultural production functions. This note reports on an application of that technique to California dairy farm production, including some extensions of the basic approach. A major objective is to present additional evidence on the question of returns to scale and to develop some general conclusions from that evidence.

Literature Review

Four previous studies are summarized in table 1. The Cobb-Douglas function was employed in these studies with elasticity sum measuring returns to scale. In the four studies, the elasticity sum for analysis of covariance is smaller than for ordinary least squares, attributable to the introduction of the firm effects. Timmer's study treated each of the forty-eight contiguous U.S. states as a "farm firm" and found increasing returns using ordinary least squares but decreasing returns after firm effects were introduced, at variance with Griliches's conclusion that increasing returns held for U.S. agriculture (p. 966).

The other studies used farms as units of observation and almost always had an elasticity sum close to 1.0 (constant returns to scale) for their least square estimates, with a substantial drop in the sum occurring when firm effects were introduced. Three interrelated explanations for this decline have been proposed: (*a*) technical efficiency increases with scale, so that the interfarm function overstates the intrafarm function; (*b*) the firm constant is regarded as an additional factor of production, in effect measuring management or entrepreneurial capacity, and its absence causes a form of omission-of-variable bias; and (*c*) simultaneous-equation bias occurs in ordinary least squares and is reduced or eliminated by analysis of covariance (Hoch 1958, 1962; Mundlak; Mundlak and Hoch).

The third explanation focuses on the possibility of bias when the production function is viewed as part of a system of equations containing decision (or profit-maximizing) equations. With the specification of disturbance terms in both production and decision relations, there is danger that the function estimated by least squares will be a blend of the underlying relationships, with a strong tendency for an estimated elasticity sum of one, regardless of the true sum. However, if profit maximization occurs with respect to anticipated output defined as the production function without a disturbance term, then the only sources of simultaneous-equation bias in ordinary least squares are the firm and time effects. Such are accounted for, and the bias removed, in the analysis of covariance.

Two related points are noteworthy. First, the simultaneous-equation framework implies that more efficient firms will become larger firms by virtue of maximizing behavior given an elasticity sum less than one. Second, the simultaneous-equation bias is symmetric; if the true elasticity sum is above one, least squares estimates will understate the sum with an estimate of constant returns again the limiting case.

The analysis of covariance results have sometimes been questioned. Timmer cites Griliches as suggesting a tendency for analysis of covariance to bias the estimated elasticities downward if there are errors of measurement in the variables (p. 145). Rasmussen was so concerned about the possibility of errors of measurement causing the elasticity drop that he rejected his analysis of covariance results (Rasmussen with Sandilands)! But analysis of probability limits shows that the bias introduced by measurement error does not change as one moves from ordinary least squares to analysis of covariance (Hoch 1963). Furthermore, empirical evidence presented below shows that an elasticity sum decline is not universal.

The Setting, Samples, and Variables Employed

The California Bureau of Milk Stabilization (BMS) collects data on individual dairy farm input and output, with each farm visited every other month. Records from this survey were obtained for each of six dairy regions defined for the state and applied in estimating dairy farm production functions.

For four of the regions more than one sample was

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This paper reports on work carried out while the author was on the faculty of the Department of Agricultural Economics, University of California, Berkeley, and is a condensation of some sections of Hoch (1976). Readers interested in greater detail are directed to that publication. Quirino Paris, David Foote, and Emilie Lachmann made important contributions to the statistical analysis of this paper. Paris's Ph.D. thesis and the project reported here were initially part of a joint effort that evolved into independent studies. An anonymous reviewer and the editor of the *Journal* gave considerable help in the revision of the present paper. Giannini Foundation Research Paper No. 426.

Table 1. Elasticity Sums and Coverage in Four Previous Studies

	Elasticity Sum			
Study: Investigator and Area	Ordinary Least Squares	Analysis of Covariance	Time Span Covered	Sample Size and Units
Hoch 1962 (Minnesota)	0.991	0.832	1946–51	63 farms
Mundlak (Israel)	0.967	0.795	1954–58	66 farms
Rasmussen with Sandilands				
English[a]	1.044	0.687	1954–57	1,646 farms
Irish commercial[a]	0.978	0.787	1955–57	1,139 farms
Irish subsistence	0.763	0.589	1955–57	
Timmer (U.S.)	1.168	0.948	1960–67	48 U.S. states

[a] Averaged over four cases in each grouping.

defined, so that a total of twelve samples were obtained. More than one sample was obtained when subregions were defined, when market-milk and manufacturing-milk producers were grouped into separate categories, or when there was selection of a special sample consisting of producers who had left the survey at the time of the study.

Years covered varied between samples, reflecting availability of BMS data. The bulk of the almost 10,000 observations (92%) fell in the period 1960–64, with a relatively small number of observations in earlier years and in 1965. The number of observations per sample ranged from 318 to 1,446, with six samples near the lower bound, two of medium size with around 800 observations, and four near the upper bound with over 1,200 observations per sample. Number of farms per sample correspondingly ranged from twenty to sixty-seven. Observations available per farm showed marked variation, but the great majority of cases were on the order of twenty observations per farm. Details on sample coverage appear in Hoch (1976).

In all of the production function analyses the dependent variable was milk produced per month (in units of 100,000 pounds) measured on a 3.8% butterfat basis, so that all milk quantities would be in comparable units. This measurement was based on BMS formula converting milk of any butterfat content to its 3.8% equivalent.

Initial fitted functions were obtained by relating milk to five independent variables: feed, capital, cow service flow, labor, and operating costs. Specific definitions of variables are given in Hoch (1976).

Results for the five input cases were not very encouraging. Internal evidence suggested the existence of strong collinearity effects for some of the inputs, and it was also possible that there was an "outside" linear relation between milk output and cow service flow, a general problem in the use of "raw material" as input. Both the collinearity and raw material problems were handled by combining all the nonfeed costs into an aggregate labeled "All other input."

Besides the conventional input measures and the dummy variables for firm and year effects, additional sets of dummy variables were introduced in the production function analyses, representing months, cow breeds, and membership status in Dairy Herd Improvement Association (DHIA).

The primary vehicle of investigation was the Cobb-Douglas equation consisting of two inputs and the dummy variables expressed in simplified form as

$$Y = (KFTMBD)Z_1^{\alpha_1}Z_2^{\alpha_2}, \tag{1}$$

where Y is milk; K is an overall constant; F, T, M, B, and D are firm, year, month, breed, and DHIA effects, respectively; Z_1 is feed, and Z_2 is all other input. (The implicit index for the variables of equation (1) is fmt, where f denotes firm, m denotes month, and t denotes year.)

In practice, the logarithmic form of equation (1) is estimated with one dummy variable in each set assigned a coefficient of zero to avoid exact collinearity. For purposes of interpretation, the calculated effects were transformed to deviations from an average effect of zero in the logs and one in the antilogs.

Results

Estimates obtained for the Cobb-Douglas production functions are presented in table 2. The firm effects clearly have a crucial impact on the elasticities. In all of the "before" cases, the elasticity sum is close to one. For each of the ten market-milk samples, the elasticity sums drop after the firm effects are introduced. For each of the two manufacturing-milk samples, the elasticity sums increase. Hence, we infer decreasing returns to scale for market-milk producers and increasing returns to scale for manufacturing-milk producers. The results are generally consistent with the argument developed above that the introduction of firm effects causes the elasticity sum to diverge from constant returns. The increase occurring in the elasticity sum for the manufacturing-milk cases is worth stressing, for it tends to contradict the argument that a downward bias exists in analysis of covariance estimates. Manufacturing-milk producers were likely to face

Table 2. Estimates for Primary Equation

Region and Sample	Elasticity Estimate: Before Firm Effects Introduced $\hat{\alpha}_1$	$\hat{\alpha}_2$	$\Sigma\hat{\alpha}$	After Firm Effects Introduced $\hat{\alpha}_1$	$\hat{\alpha}_2$	$\Sigma\hat{\alpha}$	Coefficient of Mutual Determination R^2 Before	R^2 After	t-ratios (After Firm Effects) $t\ \hat{\alpha}_1$	$t\ \hat{\alpha}_2$
Sacramento Valley										
Market	0.816	0.220	1.036	0.330	0.477	0.807	0.893	0.953	18.28	8.07
Manufacturing	0.813	0.270	1.083	0.942	0.292	1.234	0.840	0.879	13.39	2.50
Left survey	0.379	0.632	1.011	0.259	0.506	0.765	0.926	0.950	4.19	5.81
Northern and Sierra mountains	0.809	0.256	1.065	0.595	0.125	0.720	0.873	0.921	12.31	1.93
San Joaquin Valley										
Northern market	0.838	0.160	0.998	0.709	0.181	0.890	0.955	0.969	26.49	5.86
Southern market	0.884	0.132	1.016	0.736	0.175	0.911	0.975	0.984	27.07	5.04
Manufacturing	0.766	0.278	1.044	0.673	0.412	1.085	0.956	0.971	13.46	5.69
North Coast	0.888	0.055	0.943	0.510	0.392	0.902	0.867	0.917	7.04	3.26
Bay area										
Northern	0.661	0.409	1.070	0.545	0.367	0.912	0.939	0.958	17.35	6.17
Southern	0.734	0.325	1.059	0.576	0.322	0.898	0.954	0.974	14.48	5.76
Southern California										
Central	0.752	0.263	1.015	0.484	0.214	0.698	0.969	0.981	15.67	5.65
Peripheral	0.684	0.391	1.075	0.469	0.107	0.576	0.942	0.969	8.13	1.36
Average 10 market samples	0.745	0.284	1.029	0.521	0.287	0.808	0.929	0.958	15.10	4.89
Average 2 mfg. mkt. samples	0.790	0.274	1.064	0.808	0.352	1.160	0.898	0.925	13.43	4.10

an institutional situation of relatively low product price and a good deal of fixed input including human capital. Under these circumstances, increasing returns (or declining average costs) seems plausible.

The average over the ten market milk cases yields an elasticity sum around 0.8 in the "after" case, a result that conforms to the results of the Hoch (1962) and Mundlak studies shown in table 1. There is considerable variation between samples, however, with the "after" elasticity sum ranging from around 0.6 to 0.9. Samples from a given region usually have very similar elasticity estimates (usually less than one standard error apart). There was something of a reverse association between elasticity sum and scale of operation. Southern California had the largest average firm sizes and the lowest elasticities; the manufacturing samples had average firms that were small in size and showed increasing returns; and most of the other samples had in-between average firm size and in-between elasticity sum. (Average output for the Southern California cases was about 4 times the average for the manufacturing cases, and about 1.5 to 2 times that of most of the other samples.) There appears a suggestion of the classical S-shaped production function.

The significance of each set of dummy variables was tested and all were statistically significant. For most of the samples, the year effects showed a clear upward trend indicating that the production function was shifting up over time. Table 3 presents year effects averaged over all of the samples, and the upward trend is manifest for all years except 1965, perhaps reflecting a relatively small number of observations in that year. The possibility that the pattern over time might be explained by pasture conditions, presumably in turn reflecting weather variations, was examined by comparing the year effects to both current and lagged indexes of pasture conditions (data from Desai and Henderson). Little in the way of an overall relation emerged, lending some support to the hypothesis that the upward trend can be best interpreted as an indicator of technological advance.

The time effects had next to no impact on returns to scale. Typically, the elasticity sum showed a small decline (on the order of 0.01) in moving from ordinary least squares to time effects only.

It was initially hypothesized that membership in the DHIA would have a positive effect on productivity with higher output for given input. There was some confirmation for this hypothesis. However, the confirmation seemed much stronger be-

Table 3. Estimated Year Effects, Averaged Over All Samples

Year	Average Year Effect[a]	Number of Cases
1958	0.783	1
1959	0.884	4
1960	0.940	9
1961	0.985	11
1962	0.976	12
1963	1.000	12
1964	1.032	11
1965	0.980	6

[a] The 1963 effect was set equal to 1.000 for all samples.

fore firm effects were introduced, with DHIA effects estimated as above one in eleven of twelve samples with seven effects being significant. After firm effects were introduced, only eight of the effects were above one and only four were significant. The average over the twelve samples was 1.046 in the "before" case and 1.008 in the "after" case. Perhaps better operators tend to join the DHIA, and not accounting for such an association may yield an overstatement of the benefits of DHIA membership.

This result suggests by analogy that measured benefits of extension work and education may sometimes be overstated. The DHIA case and the more general cases of extension work and education can involve a selection process including self-selection so that participants in the activity are initially of higher quality. Not accounting for the underlying quality differences then yields a form of omission-of-variable bias and leads to overstatement of the benefits attributed to the information service or to the educational process. This bias probably occurs in the results obtained by Müller, who found a considerable effect attributable to an "information" variable. In addition, the absence of firm effects in his formulation gave essentially constant returns to scale for his elasticity estimates, corresponding to the "before" results in table 2.

There was good graphic evidence that the firm effects were distributed normally, and the hypothesis of normality was accepted by statistical test. In the antilogs, the firm effects implied that for given input 67% of all farms would produce between 0.85 and 1.17 of average farm output, while 95% would produce between 0.73 and 1.37 of that output. The firm effects had a high correlation with output, averaging 0.72 over all samples, and they correlated well with independent evaluations of producer efficiency made by the BMS field men.

The distribution of farm sizes can be explained by the production elasticities and the firm effects. As the elasticity sum approaches one, small differences in firm effects lead to much more pronounced differences in size of firm. For instance, at an elasticity sum of 0.99, a firm that is 10% more efficient than average will have an equilibrium output some 14,000 times the average output. Such results may suggest why agriculture is a competitive industry, while others tend to be oligopolistic or monopolistic. A firm with equilibrium output many orders of magnitude above its competitors will dominate the market and probably drive its competitors out of business well before it reaches equilibrium. Hence, we ought not expect a competitive industry to have firms with both an elasticity sum close to one and even modest differences in firm effects. If there is reason to expect differences in management ability between firms, an estimated elasticity sum approaching constant returns to scale should be a cause of concern and not of congratulation.

Supply elasticities can be derived from production function elasticities (α_q, $q = 1, 2, \ldots, Q$). Here again, returns to scale estimates are of considerable consequence. Under plausible assumptions, the elasticity of output with respect to price is $\Sigma\alpha_q/(1 - \Sigma\alpha_q)$. Hence, the supply elasticity will be greater than 1.0 if $\Sigma\alpha_q$ is above 0.5, and it approaches infinity as $\Sigma\alpha_q$ approaches 1.0. That latter result may be behind the complaint of Wipf and Bawden who have argued that supply curves derived from production functions are unreliable (p. 177); a major element of their critique is that elasticities appear too high relative to direct estimation of supply. Once again, a production elasticity sum below one consistent with the use of firm effects yields more reasonable results than constant returns to scale.

Subsidiary Investigations

Several subsidiary investigations seem noteworthy. In the first, a quadratic production function was estimated. Some results here were disappointing, with some coefficients having the opposite of the expected sign and with occasional deletion of a quadratic term because of collinearity. However, marginal returns estimated from the quadratic equation agreed in magnitude and in shifts with those from the Cobb-Douglas function for individual samples and for the average over the individual samples (table 4).

A second subsidiary investigation involved the introduction of slope shifters as well as the intercept shifters of the primary equation. Each elasticity then contained a time and firm effect as well as a constant element. Because the slope shifter approach introduces a great many additional variables, a degree of freedom problem can arise, avoided here by employing firms having a relatively large number of observations to form eleven market samples with about a dozen firms in each sample. Four variants were obtained, depending on whether slope shifters and/or intercept shifters were brought into the equation. Elasticity sums for these four cases averaged over the eleven samples employed were as follows: (*a*) 0.676, given both slope and

Table 4. Marginal Return Estimates, Averaged Over Ten Market Milk Samples

	Before Firm Effects		After Firm Effects	
	Quadratic	Cobb-Douglas	Quadratic	Cobb-Douglas
Feed	1.385	1.468	1.148	0.960
All other input	0.786	0.748	0.568	0.741

Note: Marginal return equals return for an incremental expenditure of $1, calculated at average levels of input and output.

intercept shifters, (*b*) 0.842, given slope shifters only, (*c*) 0.701, given intercept shifters only, and (*d*) 1.026, given no shifters (ordinary least squares).

Cases (*c*) and (*d*) parallel earlier results, with an elasticity sum a bit over 1.0 prior to an introduction of firm and time effects, and a substantial decline in the elasticity sum after those intercept shifters are introduced. Case (*b*) introduces slope shifters but omits the intercept shifters and its elasticity sum (on average) falls between the extremes of cases (*a*) and (*d*). Case (*a*) has both slope and intercept shifters, and some changes in elasticity sum occurred relative to case (*c*) at the level of the individual sample. However, the overall average for case (*a*) is essentially the same as that for case (*c*), and the individual differences were generally not large, which suggests that the differences are not very important.

These results support the use of case (*c*) (equivalent to the primary equation employed) when the objective is estimation of average values of elasticities. With the use of slope shifters there is the additional possibility of investigating systematic variation in elasticities, but results here appeared only mildly encouraging. Multicollinearity was a major problem, and disaggregation to the individual firm gave great variability in results with negative elasticities fairly common.

Maddala discusses an alternative to fixed effects analysis of covariance in pooling cross-section and time-series data, in which effects are treated as random. His rationale for the approach includes the arguments that "rarely is it possible to give a meaningful interpretation to the dummy variables," and that in some cases analysis of covariance entails the loss of a considerable number of degrees of freedom (p. 341). The arguments seem germane to the slope-shifting case but do not seem very convincing in the context of the primary investigation here, given the emphasis on interpreting and drawing inferences from the firm and time effects and the availability of many observations on individual firms.

Conclusions

Economists often express the strong intuition that constant returns to scale is an accurate representation of nature. In contrast, the empirical results here show a marked divergence from constant returns, explainable on the basis of a detailed model of firm behavior. Furthermore, the assumption of constant returns can lead to various embarrassments, including infinite supply elasticity and the likely incompatibility of competition and even small differences in technical efficiency between firms. In the empirical results, alternative approaches and functional forms often gave remarkably similar results, suggesting that the same underlying reality can be perceived—even if dimly—from different vantages.

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The Retail-Farm Price Ratio, the Farmer's Share, and Technical Change

Allen K. Miedema

Technical change in the food marketing industry has been causally linked to the secular increase in the marketing margin, i.e., the margin between product prices at retail and prices of the related raw farm products. Technical change has also been adduced by Lianos to explain the decline in the relative share of farm workers. However, this work generally omits a formal neoclassical model of technical change that accounts for imperfect competition in input and product markets.

This paper synthesizes previous work by Muth and by Gardner in developing a more complete specification of the effects of technical change. This specification allows for noninfinite product demand and factor supply elasticities. These theoretical results are then analyzed empirically to derive some specific quantitative implications of technical change for the food marketing industry. Lianos' empirical estimate of the degree of capital-biased technical change in agriculture is reinterpreted with these alternative neoclassical specifications.

A Synthesis of Previous Results

In a recent article in the *Journal* Gardner examined changes in input-retail price ratios and input shares induced by exogenous perturbations in product demand and in factor supply functions. The analysis was based on the standard one-product, two-input model. That model is first restated in a form that differs unsubstantively from that given by Gardner. Another brief reformulation is given in logarithmic differentials as derived by Muth. With this reformulation Gardner's main results can be reproduced and extended with simple recombinations of Muth's results.

In the one-product, two-factor models equilibrium of the marketing industry is described by six equations: (*a*) a retail product (x) demand function (D); (*b*) a marketing industry production function (f), which is assumed to be linear homogeneous in the two inputs, a and b; (*c*) and (*d*) the marginal conditions on factor payments, i.e., equalities between factor prices (P_a and P_b) and the products of retail price (P_x) and marginal products (f_a and f_b); and (*e*) and (*f*) factor supply functions. These equations define the following system:[1]

(1) $$x = D(P_x),$$
(2) $$x = f(a, b),$$
(3) $$P_a = P_x f_a,$$
(4) $$P_b = P_x f_b,$$
(5) $$a = g(P_a),$$
and
(6) $$b = h(P_b),$$

where, as in Gardner's paper, a is purchased agricultural commodities, b is other marketing inputs, and x is food sold at retail. Prices are defined accordingly.

Muth has shown that equations (1) through (6) can be reformulated as[2]

(7) $$ZY = R,$$

where

$$Z = \begin{bmatrix} -1/\eta & 0 & 0 & 1 & 0 & 0 \\ 1 & -k_a & -k_b & 0 & 0 & 0 \\ 0 & k_b/\sigma & -k_b/\sigma & -1 & 1 & 0 \\ 0 & -k_a/\sigma & k_a/\sigma & -1 & 0 & 1 \\ 0 & -1/e_a & 0 & 0 & 1 & 0 \\ 0 & 0 & -1/e_b & 0 & 0 & 1 \end{bmatrix},$$

$$Y = \begin{bmatrix} EX \\ Ea \\ Eb \\ EP_x \\ EP_a \\ EP_b \end{bmatrix}, \text{ and } R = \begin{bmatrix} \alpha \\ \delta \\ \delta + \epsilon \\ \delta - (k_a/k_b)\epsilon \\ \beta \\ \gamma \end{bmatrix}.$$

The notation is defined in table 1. The complete mathematical derivations of the technical change parameters (δ and ϵ) are in Muth.

The solution of the system in equation (7) is $Y = Z^{-1}R$. Because of the way R is defined, Y may be

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[1] None of these equations explicitly reflects its dependence upon any exogenous variables, but the presence of these exogenous variables in the demand, production, and factor supply functions is explicitly assumed. Following Muth, "the effect of changes in any such variables will be treated as a shift in one or more of these functions" (p. 222).

[2] Although Muth presents none of his work with matrix notation, the following matrix system is an exact restatement of his reformulated system. The five parameters (excluding k_a and k_b) in the vector R represent the combined shifting effects of the (omitted) exogenous variables in equations (1) through (6). Relative changes are defined as the logarithmic differentials of any variable. Thus, the relative change dt/t for an arbitrary variable t is the percentage change divided by 100.

Table 1. Variable Definitions

Variable	Definition
EX	$d(\ln x) = dx/x$ (the operator E is similarly defined for other elements of Y)
η	Own price elasticity of demand for x
e_a	Own price elasticity of agricultural commodity supply
e_b	Own price elasticity of marketing input supply
σ	Elasticity of substitution between a and b
k_a	Cost share imputed to agricultural commodities
k_b	Cost share imputed to marketing inputs
α	Relative change in food prices at any quantity on the new food demand curve
β	Relative change in the supply of a (the vertical relative shift in the supply function)
γ	Relative change in the supply of b
δ	Neutral component of technical change, defined as the relative (and equal) change in the marginal products of a and b (which is equal to the relative change in output) for the input quantities prior to the technical change
ϵ	Factor-biased component of technical change, defined as the relative change in a's marginal product, holding output constant for the input quantities used prior to the technical change

redefined as a linear function of the vector of exogenous perturbations (S):

$$(8) \qquad Y = Z^{-1}R = \Delta^{-1}GS,$$

where $\Delta = \sigma\eta - \sigma(k_a e_a + k_b e_b) + \eta(k_b e_a + k_a e_b) - e_a e_b$, usually a negative scalar defined by D'' in Muth and by $-D$ in Gardner, $G = [g_{ij}]$, a 6×5 matrix whose row elements are directly available as the coefficients (excluding D'') of the five elements of S in equations (24) through (29), respectively, of Muth's appendix, and $S = (\alpha, \beta, \gamma, \delta, \epsilon)'$.

To examine the shifting effects of exogenous variables in the food demand function, the agricultural commodity supply function, and the marketing input supply function, Gardner inserted three shift variables—N, W, and T, respectively—into those functions. Therefore, the following three parameters appear in his main results:

$$(9) \quad \eta_N = d(\ln x)/d(\ln N);\ e_W = d(\ln P_a)/d(\ln W); \text{ and } e_T = d(\ln P_b)/d(\ln T).$$

Muth, on the other hand, expressed the product demand and factor supply function shifts—α, β, and γ, respectively—as *ad valorem* shifts in the direction of the price axis. Thus, he defined α as the "relative increase in price at any given quantity on the new demand schedule" (Muth, p. 223). The parameters β and γ are accordingly defined as the relative increases in the supply prices of factors a and b, respectively, at any given quantity. Therefore, Muth's shift coefficients may be expressed in terms of Gardner's three parameters in equation (9) as

$$(10) \quad \alpha = -(\eta_N/\eta)\, d(\ln N);\ \beta = e_w\, d(\ln W); \text{ and } \gamma = e_T\, d(\ln T).$$

The appropriateness of these expressions, which follow from the inverse functions related to equations (1), (5), and (6), may be verified in Muth.

Since Gardner did not consider the effects on the factor share of agricultural commodities resulting from an exogenous shift in the marketing input supply function, that analysis is presented here for completeness. It follows definitionally that[3]

$$(11) \quad d(\ln k_a/\gamma) = (g_{53} + g_{23} - g_{43} - g_{13})/\Delta, \text{ for } S = (0, 0, \gamma, 0, 0)',$$
$$= [(1 - \sigma)k_b e_b(e_a - \eta)]/\Delta.$$

Since Δ is usually negative, the sign of equation (11) is determined by the size of σ, as is the case for the change in a's share resulting from a shift in the agricultural commodity supply function (see Gardner's equation (23)). If $\sigma < 1$, the farmer's share will fall as the marketing input supply function shifts upward. For example, if skilled labor specific to farm product marketing, e.g., butchers, were to become relatively scarcer, the marketing input supply function would shift upward and the farmer's share of the food dollar would decline. In any event identical conditions on the value of σ insure (except when $\sigma = 0$) opposite directional effects on the farmer's share from exogenous perturbations of the agricultural commodity supply function and of the marketing input supply function, respectively.

The Effects of Technical Change

Since Muth's formulation contains two additional shift parameters relating to neutral and factor-biased technical change, respectively, the model is extended to examine their effects on the retail-farm price ratio and on input shares. This approach allows the relaxation of the traditional assumption of infinite product demand and factor supply elasticities in the analysis of the effects of technical change.

The two shift parameters (δ and ϵ) decompose the components of technical change in the marketing industry into intensity and bias, respectively (table 1). Although both parameters are defined at the pretechnical change equilibrium position that is a disequilibrium position after the technical change, they completely describe the change in the shape of the production isoquants. Just as Gardner's results and equation (11) summarize the new equilibria that result from changes in the shape of the product demand and input supply functions, a similar analysis summarizes the new equilibria that result from a change in the shape of the production isoquants.

[3] Transformed back to Gardner's notation using the expression for γ from equation (10), this result can be restated as $E_{S_a T} = -e_T (\sigma - 1) S_b e_b (\eta - e_a)/D$.

Technical Change and the Retail-Farm Price Ratio

The effect of neutral technical change on the retail-farm price ratio is derived from equation (8) as

$$(12)\qquad d[\ln (P_x/P_a)]/\delta = (g_{44} - g_{54})/\Delta, \text{ for } S = (0, 0, 0, \delta, 0)', = \Lambda/\Delta,$$

where $\Lambda = \sigma(k_a e_a + k_b e_b) + k_b(e_a - e_b) + e_a e_b - \eta(\sigma + e_b)$. There are four feasible values of parameter combinations in equation (12) to explore in completely examining the directional impact of neutral technical change on the retail-farm price ratio. All such evaluations recognize that Δ is negative.

Case 1: $e_a > e_b$ or $e_a = e_b$. When the elasticity of agricultural commodity supply exceeds (or equals) that of market input supply, all terms in the numerator (Λ) of equation (12) are positive. The whole expression is negative for normal values of the parameters, so that the retail-farm price ratio declines with neutral increases in factor productivity when $e_a > e_b$ or when $e_a = e_b$.

Case 2: $e_a < e_b$, $\sigma > 1$. Since both e_a and e_b are positive and e_a is assumed less than e_b, e_a can be expressed as a fraction τ, which lies in the open interval (0,1), of e_b:

$$(13)\qquad e_a = \tau e_b,\ 0 < \tau < 1.$$

When the expression for e_a in equation (13) is substituted into the numerator (Λ) of equation (12) the numerator becomes

$$(14)\qquad \Lambda = \lambda_0 + \lambda_1 \tau,$$

where $\lambda_0 = k_b e_b(\sigma - 1) - \eta(\sigma + e_b)$ and $\lambda_1 = \sigma k_a e_b + k_b e_b + e_b^2$. When $\sigma > 1$, $\lambda_0 > 0$ for all normal parameter values; also $\lambda_1 > 0$ normally. Therefore, even when $e_a < e_b$, the retail-farm price ratio declines with neutral increases in factor productivity when $\sigma > 1$.

Case 3: $e_a < e_b$, $\sigma < 1$, $-(\lambda_0/\lambda_1) < 1$, $-(\lambda_0/\lambda_1) < \tau < 1$. Since Λ is an increasing linear function of τ, Λ assumes positive values for all $\tau > -(\lambda_0/\lambda_1)$. If $-(\lambda_0/\lambda_1) < 1$, there is some range of values for τ that implies a positive numerator in equation (12), namely, the range of values for which $\tau > -(\lambda_0/\lambda_1)$. When $\lambda_0 > 0$, despite the fact that $\sigma < 1$, P_x/P_a declines with positive neutral technical change. When $\lambda_0 < 0$, P_x/P_a is more likely to decline under this type of technical change if the elasticity of agricultural commodity supply is close to (a large fraction of) that of marketing inputs.

Case 4: $e_a < e_b$, $\sigma < 1$, $\tau < -(\lambda_0/\lambda_1)$. It follows from case 3 that $\Lambda < 0$ when $e_a < e_b$ and $\sigma < 1$ if $\tau < -(\lambda_0/\lambda_1)$. Since τ is always positive, this condition requires that λ_0 be negative. This condition occurs when $\eta = 0$. When $\sigma = 0$ it occurs only when the absolute value of η is less than k_b. In the limiting case when both σ and η equal 0, the critical value of τ is $1/(1 + e_b k_b^{-1})$. For example, when $\sigma = \eta = 0$, $e_b = 2$, and $k_b = 0.5$, the critical value of τ is 0.2. If under these conditions the elasticity of agricultural commodity supply (e_a) is less than $0.2e_b$ or 0.4, the retail-farm price ratio increases with a neutral increase in factor productivity. In general both extremely limited substitutability between agricultural commodities and marketing inputs and an inelastic demand for the retail product are necessary conditions for the retail-farm price ratio to increase in the presence of neutral technical change.

The effect of b-saving technical change on the retail-farm price ratio is similarly derived from equations (8) as

$$(15)\qquad d[\ln (P_x/P_a)]/\epsilon = (g_{45} - g_{55})/\Delta, \text{ for } S = (0, 0, 0, 0, \epsilon)', = \sigma(k_a e_a + k_b e_b - \eta)/\Delta.$$

Since the numerator in equation (15) is normally positive the whole expression is negative. The implication is that technical change that is b-saving will reduce the retail-farm price ratio.

Technical Change and Factor Shares

Equation (8) can also be used to assess the impact of neutral technical change on the share of revenues imputed to agricultural commodities:

$$(16)\qquad d(\ln k_a)/\delta = (g_{54} + g_{24} - g_{44} - g_{14})/\Delta, \text{ for } S = (0, 0, 0, \delta, 0)', = [k_b(1 + \eta)(1 - \sigma)(e_b - e_a)]/\Delta.$$

The three parenthesized expressions in the numerator may be positive, zero, or negative. If any one is zero, a's factor share does not change when neutral technical change occurs. Of the remaining eight possibilities, four imply that a's factor share increases and four imply that it decreases with neutral increases in factor productivity.[4] No more specific general statement can be made.

However, if the elasticity of agricultural commodities supply is lower than that of marketing inputs, if the elasticity of substitution between the two factors is less than unity, and if the demand for food is inelastic ($\eta > -1$), then neutral increases in factor productivity decreases the farmer's share of the food dollar.

The effect of a-biased technical change on the farmer's share of the food dollar can be derived as

$$(17)\qquad d(\ln k_a)/\epsilon = (g_{55} + g_{25} - g_{45} - g_{15})/\Delta, \text{ for } S = (0, 0, 0, 0, \epsilon)', = M/\Delta,$$

where $M = \mu_0 - \mu_1\tau$, $\mu_0 = -\sigma[-\eta + e_b(1 - 2k_a)]$, and $\mu_1 = \sigma e_b(-\eta + e_b + 2k_a)$.

Four feasible values of parameter combinations in equation (17) determine the directional impact of a-biased technical change on the farmer's share of the food dollar.[5]

[4] Since each of the three factors may be either positive or negative, the products of each of the eight possible signed combinations imply a positive or a negative sign for the numerator of equation (16).

[5] It is possible to identify a potential bias in Gardner's estimate

Case 1: $\tau > 1$. Since this condition implies that $e_a > e_b$, it follows by substituting $\tau = e_a/e_b$ into the expression for M that $M < 0$ when $\tau > 1$. Therefore, whenever the elasticity of agricultural commodity supply exceeds that of marketing inputs positive a-biased technical change increases the farmer's share of the food dollar.

Case 2: $\mu_0 < 0, \tau \lesseqgtr 1$. Since the numerator ($M$) in equation (17) is a declining function of τ (μ_1 is normally positive), M is always negative if $\mu_0 < 0$. This occurs if $k_a < (e_b - \eta)/2e_b$. Thus, *ceteris paribus*, the smaller the share of agricultural commodities is to begin with, the more likely it is to rise as a-biased technical change occurs.

Case 3: $\mu_0 > 0$, $(\mu_0/\mu_1) < 1$, $(\mu_0/\mu_1) < \tau < 1$. Since M is a declining function of τ, M assumes negative values for all $\tau > \mu_0/\mu_1$. When $(\mu_0/\mu_1) < 1$, those values of τ above μ_0/μ_1 imply a negative value for M and an increase in k_a resulting from an increase in ϵ. Therefore, agricultural supply elasticities close in value to those of marketing inputs are more likely to be accompanied by increases in the farmer's share of the food dollar when the positive agricultural commodity biased technical change occurs.

Case 4: $\mu_0 > 0$, $\tau \leq (\mu_0/\mu_1)$. Following the preceding logic, these conditions imply that M assumes a positive (or zero) value and hence that the farmers share of the food dollar falls (remain constant). Consequently, if the elasticity of agricultural commodity supply is small relative to that of marketing inputs, the farmer's share of the food dollar is more likely to fall when a-biased technical change occurs.

Empirical Applications

The implications of these results for agriculture can be further examined by empirical applications of equations (12), (15), (16), and (17). First, a sensitivity analysis is presented based on various ranges of reasonable parameter values. Then, the theory is applied to explain shifts in the farm product price-farm wage ratio and in farm labor's relative share in the farm production stage rather than in the marketing stage.

The four equations can be interpreted as elasticities since each is a ratio of logarithmic differentials. Given the precise definitions of δ and ϵ in table 1, equation (12) is the elasticity of the retail-farm price ratio with respect to neutral technical change, defined as an equal relative change in the marginal products of both a and b. Equation (16) similarly defines the elasticity of the farmer's share with respect to neutral technical change, while equation (15) can be interpreted as the elasticity of the retail-farm price ratio with respect to a-biased technical change defined as the relative change in a's marginal product that leaves output unchanged for the two inputs used prior to the change. Finally, equation (17) is the elasticity of the farmer's share with respect to a-biased technical change. All four elasticities represent percentage changes in variables associated with equilibrium positions before and after technical change.

In the sensitivity analysis it is assumed—as in Gardner's table 1—that reasonable hypothetical parameter estimates for these equations are $k_a = 0.5$, $\eta = -0.5$, $e_a = 1.0$, $e_b = 2.0$, and $\sigma = 0.5$. (Hereafter these estimates are referred to as the baseline values.) The analysis is completed by computing the value of each of the four equations eighty-four times: twenty-one times in increments of 0.25 over the closed interval [0,5] for each of three parameters (e_a, e_b, and σ) and over the closed interval [−5,0] for η while all other parameters are held at their baseline values. The results are shown in figures 1 through 4. For example, the plot labeled e_b in figure 1 shows the values of equation (12) when e_b is varied from 0 to 5 and all other parameters are held constant at their baseline values.

Figure 1 shows that over all of the chosen parameter values the retail-farm price ratio declines in the presence of neutral technical change. Over the selected parameter ranges induced changes in the ratio are least sensitive to changes in the elasticity of substitution. As dictated by the theoretical results, the retail-farm price ratio declines when a-biased technical change occurs (figure 2). Changes in the elasticity of farm product demand induce virtually no change in the ratio.

Figure 3 summarizes the effects of neutral technical change on the farmer's share. These calculations illustrate that the direction of the change is not easily predictable. For the baseline parameter values the farmer's share would decline with neutral technical change. Figure 4 shows that for all hypothesized parameter value combinations the farmer's share will rise with a-biased technical change, even when $e_a = 0$. When $\sigma = 0$ there is no change in the farmer's share, and it changes very little in response to changes in the product demand elasticity.

The sources of change in the relative share of labor in agriculture can also be analyzed. Lianos determined that technological progress in American agriculture has been capital using. His preferred estimate of the bias (B) of technological progress, defined strictly as the average difference between the logarithmic differential of the marginal product of capital and that of labor, is 0.129. This estimate

of the elasticity of substitution. As Gardner points out, $[d(\ln k_a/s_i)]/[d[\ln (P_x/P_a)]/s_i] = \sigma - 1$, for $i = 1, 2$, where s_i is the ith element of S (p. 406). Examination of equations (10) and (11) and Gardner's equation (17) reveals that the foregoing relationship also holds for $i = 3$, but this relationship does not hold for $i = 4$ or 5. From equations (12) and (16) and from equations (15) and (17), the solutions for $i = 4$ and $i = 5$ are $[d(\ln k_a/s_i)]/[d[\ln (P_x/P_a)]/s_i] \doteq [k_b(1+\eta)(1-\sigma)(e_b - e_a)]/\Lambda$ for $i = 4$ and $M/[\sigma(k_a e_a + k_b e_b - \eta)]$ for $i = 5$. Definitions of Λ and M are found in equations (12) and (16). These results imply that one has to exercise some care in interpreting $d(\ln k_a)/d[\ln (P_x/P_a)]$ as $\sigma - 1$. This relationship holds only in the absence of technical change.

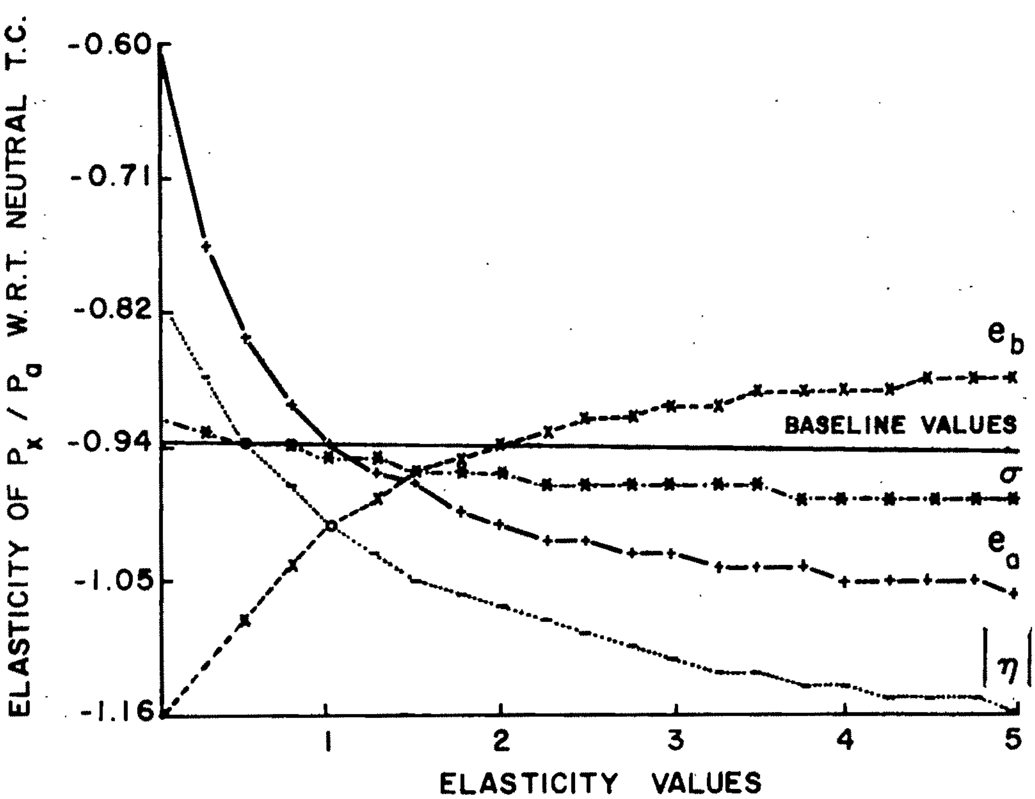

Figure 1. Sensitivity of equation (12) to variations in four elasticities

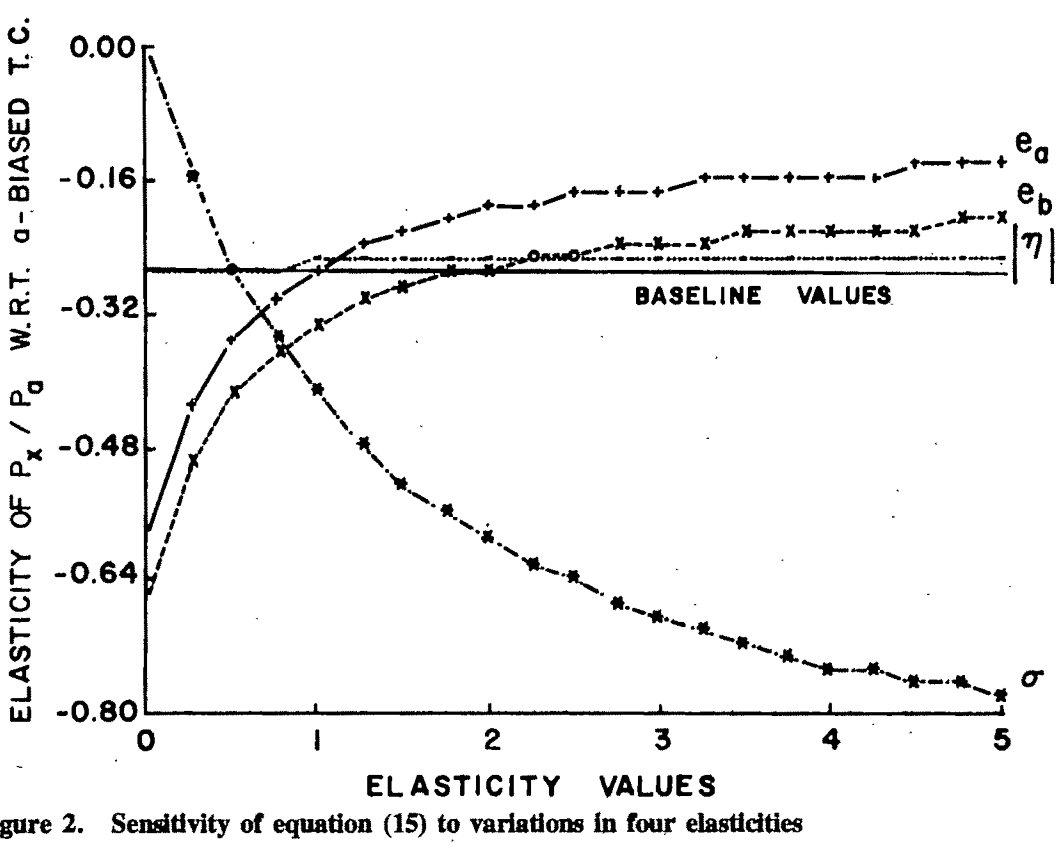

Figure 2. Sensitivity of equation (15) to variations in four elasticities

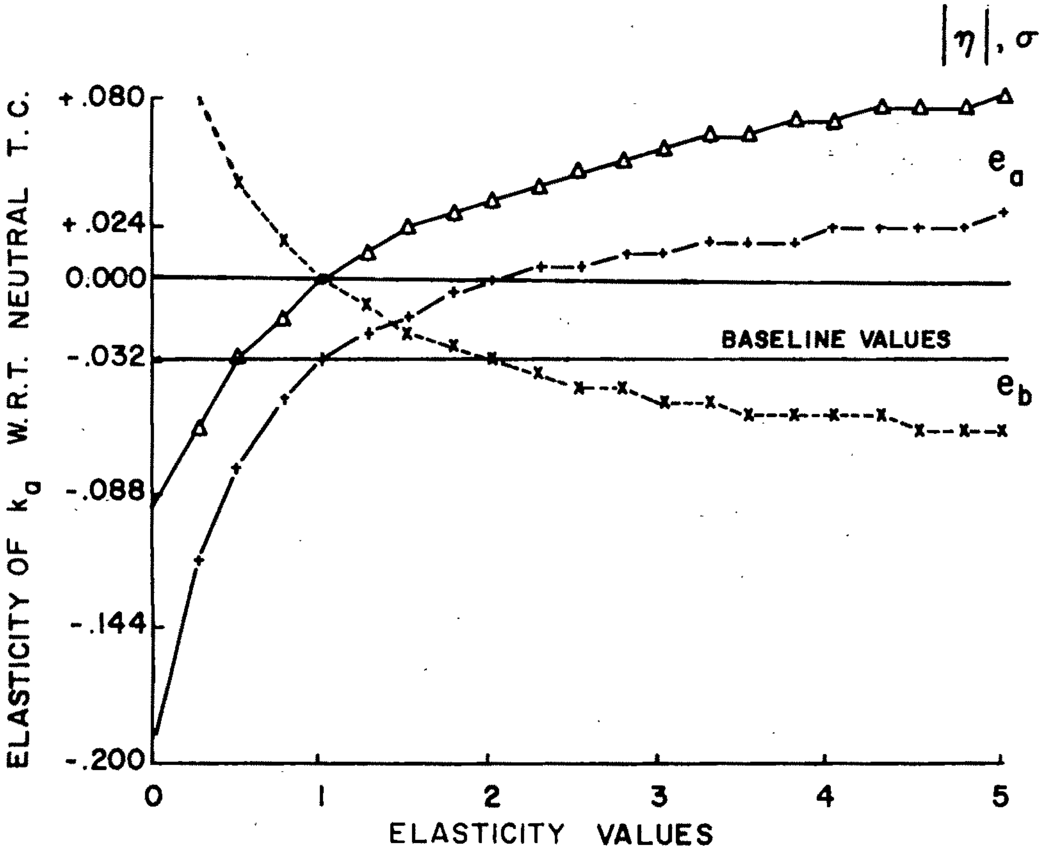

Figure 3. Sensitivity of equation (16) to variations in four elasticities

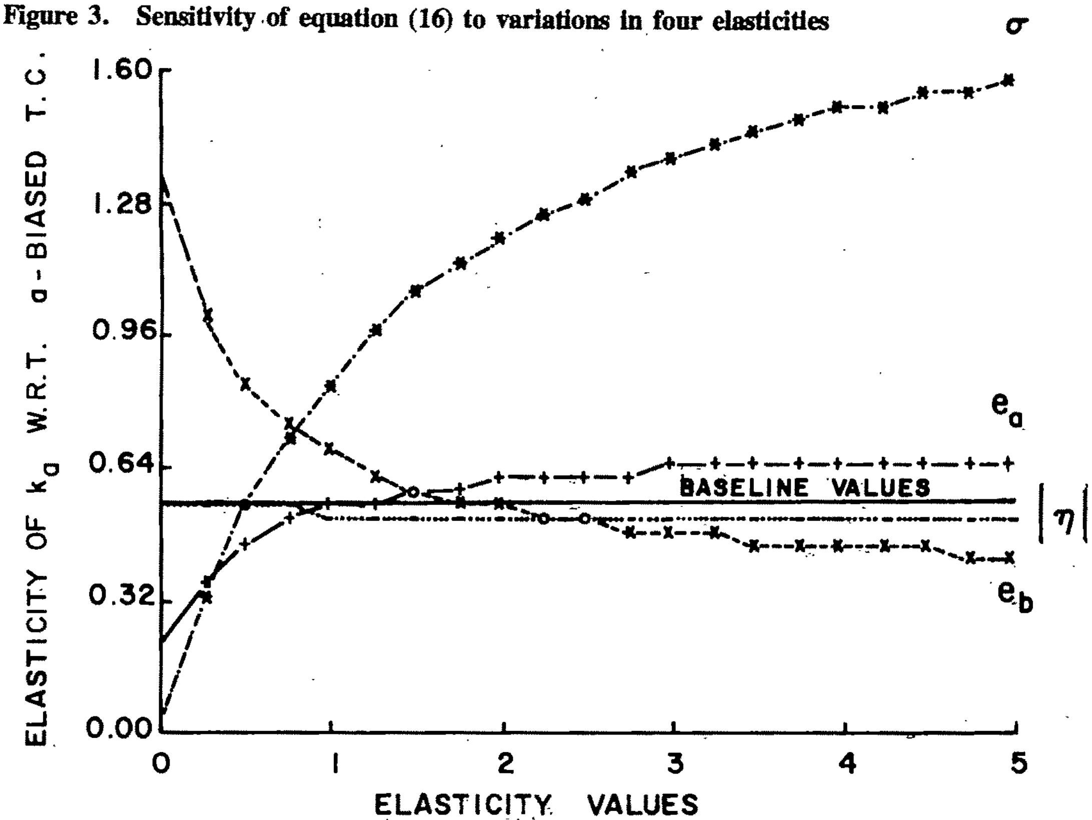

Figure 4. Sensitivity of equation (17) to variations in four elasticities

and Lianos' first estimate of 0.294 for the relative share of capital imply a value of ϵ equal to -0.09107.[6]

It is of interest to determine the percentage change in the farm product price-farm wage ratio and in the relative share of labor that accompany such a level of biased technical change. The elasticity of labor is available as the inverse of the coefficient on the farm labor variable in Wallace and Hoover. This estimate implies an elasticity of farm labor supply of about 18.87. If estimates of the elasticity of farm product supply (e_x) of the elasticity of substitution and of relative shares are available, these data in conjunction with the estimate of the labor supply elasticity are adequate to estimate the elasticity of capital supply.[7] Griliches's long-run estimate of e_x equal to unity is assumed, and Lianos' estimates of $\sigma = 1.524$ and $k_a = 0.294$ are used. These values imply an elasticity of capital supply of 0.336. All of these values are substituted into equations (15) and (17), which are then multiplied by -0.09107 to determine the two associated relative changes. These calculations are completed for two estimates of the elasticity of farm product demand, -0.5 and -0.35 (see Lianos for the sources of these estimates). The results suggest that Lianos' estimate of B implies a 3.85% annual increase in the farm product price-farm wage ratio in the first case and a 4.17% annual increase in the second case. Similarly, the relative share of labor decreases 16.87% annually in the first case and 16.69% in the second.

These results obviously imply much larger annual percentage decreases in farm labor's relative share than those predicted by Ferguson's model used by Lianos. The main reason for this is that equation (17) accounts for noninfinite factor supply and product demand elasticities while Lianos' basic model assumes all these elasticities are infinite. Lianos' model apparently is a better predictor than the one presented here, but he attributes all of the nonprice induced shifts in the relative share of labor to technical change. A major point of this and Gardner's paper is that many exogenous influences simultaneously affect movements in this share. (In terms of this paper all of the elements of S are possibly nonzero during any time period.) Therefore, the partial effect of Lianos's estimate of bias is larger than he indicated when reasonable estimates of factor supply and product demand elasticities are incorporated. Other exogenous effects, such as shifts in the factor supply and product demand functions, are likely responsible for observed reductions in the relative share of labor that are smaller than those predicted here.

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[6] In the notation of this paper $B = d(\ln f_b) - d(\ln f_a)$. Muth's definition of ϵ implies that $B = -\epsilon(1 + k_a/k_b)$. Consequently, $B = 0.294$ implies the value of ϵ given in the text, assuming $k_b = 0.294$.

[7] This can be accomplished by solving the equation expressing the derived elasticity of product supply for e_b; this equation is given in both Muth and Wisecarver.

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Accuracy of Least Squares Computer Programs: Another Reminder

William T. Boehm, D. J. Menkhaus, and J. B. Penn

In 1943, Hotelling reported on the potential inaccuracies of least squares algorithms. Since then, numerous studies have been published presenting the results of comprehensive tests of widely used least squares routines, algorithm refinement, and assessments of error bounds. Papers by Beaton, Rubin, and Barone; Freund; Ling; Longley; and Wampler provide a sample of the literature available. Most of the formal research on these issues has been conducted by statisticians, mathematicians, or computer scientists and/or has been published in the scientific journals of those professions. While probably aware of potential computer inaccuracies, agricultural economists and others using least squares programs in their research are often forced to rely on both the software packages and hardware available at their research station. They may or may not be familiar with the literature being published on computational accuracy and as a result may not explicitly question the accuracy of either the software or the hardware they use. The issue is real and of some importance. In 1976, for example, SPSS, Inc., distributed a newsletter warning users of that major software package that there "is a catastrophic error in the discriminant procedure. The discriminant function coefficients are incorrectly computed" (p. 2). While the problem was corrected once it was discovered, consider the plight of those who used the discriminant procedure from that package to conduct research and are now anxiously awaiting comments from reviewers regarding the publishability of their results and the associated policy implications.

The purpose of this note is to demonstrate once again and in a form meaningful to program users that even though substantial improvements in computer software and hardware have been made in recent years, computational accuracy can still be a problem. While it is admitted that accuracy is a multidimensional issue, our concern in this paper is with computational accuracy. The procedure employed is that used by Wampler. Results obtained from selected regression routines available to agricultural economists at four land grant universities are examined and compared.

No formal attempt is made here to explain why, for certain problems, some routines and/or machines may generate more accurate results. Such a discussion is beyond the scope of this note and would in large measure duplicate the literature now available. The interested reader is referred to Ling.

Procedures

Two problems, identified as equations (1) and (2), were used for the test. Values of the "endogenous" variables (Y) for the test were calculated from the following equations:

$$Y = 1 + X + X^2 + X^3 + X^4 + X^5, \tag{1}$$

and

$$Y = 1 + 0.1X + 0.01X^2 + 0.001X^3 + 0.0001X^4 + 0.00001X^5. \tag{2}$$

Both equations (1) and (2) are fifth degree polynomials. The values of the "exogenous" variable (X) were the integers 0, 1, 2, . . . , 20. True values for the parameters are, of course, the values used to calculate Y. There is no error term and therefore the true $R^2 = 1$.

The simple correlation coefficients among the X's were all greater than 0.816, six of the ten were greater than 0.958, and three were greater than 0.986. The high linear association between the regressors and the large variation in the data partially explain why these problems present such difficulty in obtaining consistently accurate parameter estimates.

Parameter estimates for the two test problems were obtained for a total of forty-two separate equations using an IBM 370 Model 165 (IBM1), CDC 6500 (CDC), IBM 370 Model 158 (IBM2), and a Xerox Sigma Seven ($\Sigma 7$) computer. The programs used included BMD2R, BMD3R, SPSS, SAS, TTLS, LSP, MDVR1 (single precision), and MDVR2 (double precision). The specific equations estimated by program and machine are summarized in table 1.

BMD2R and BMD3R (stepwise and multiple regression, respectively) are two regression options from the Biomedical Computer Programs (Dixon).

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Table 1. Summary of the Equations Estimated by Program and Machine

Program Used to Estimate Equations	Computing Machine and Location			
	IBM1 North Carolina State	CDC Purdue University	IBM2 Virginia Tech	Σ7 University of Wyoming
BMD2R	X	X	X	X
BMD3R	X	X	X	X
SPSS	X	X	X	X
SAS	X		X	
TTLS	X	X	X	
LSP		X	X	
MDVR1				X
MDVR2				X

The multiple regression routine from the relatively new Statistical Package for the Social Sciences is identified as SPSS (Nie, Bent, and Hull). SAS denotes the multiple regression option from the Statistical Analysis System originally designed at North Carolina State University (Barr and Goodnight). TTLS is a program originally developed by Stroud, Zellner, and Chau to calculate parameter estimates for systems of equations (simultaneous and seemingly unrelated regression). LSP denotes a FORTRAN multiple regression program of unknown origin that has been modified to improve its accuracy (i.e., double-precision variable arrays), simplify the data input, and provide additional information (e.g., Durbin-Watson statistic, elasticities, R^{-2}) (Boehm, Penn). MDVR identifies a program developed at the University of Wyoming Agricultural Experiment Station (Roehrkasse).

The two test problems have been classified by Wampler as being highly "ill-conditioned," the former being slightly more ill-conditioned than the latter.[1] While polynomial fitting is common in applied economic studies, problems with data matrices such as these are admittedly seldom encountered in practice.[2] Suffice it to say that if computer routines successfully handle these test problems, computational accuracy should not be a serious issue for less ill-conditioned cases.

Results

Accurate parameter estimates were obtained for only nineteen of the forty-two equations estimated. The programs failed to compute estimates for some or all parameters in fifteen of the equations. In some cases when the calculated parameters were reasonably accurate, the coefficient standard errors were considerably larger than their corresponding coefficient estimates and thus, using classical t-tests and the usual null hypothesis (i.e., H_0: $B_j = 0$), would have been judged nonsignificant. However, any calculated coefficient standard error not equal to 0 was, strictly speaking, an error.

Estimates for the residual standard error, which should be zero, were inaccurately estimated for twenty-seven of the forty-two equations. The coefficient of determination (R^2) was reasonably accurate in all but six of the equations. However, in two of these equations the reported R^2 was greater than its theoretical bound.

The general nature of the inaccuracies obtained for equation (1) is summarized in table 2. The results indicate the rather wide variation in the estimates obtained for BMD2R, BMD3R, and TTLS using different machines. They also indicate that in general similar results were obtained for BMD2R and BMD3R on the two IBM machines at different locations. In fact, equation (1) estimates obtained using IBM equipment and BMD2R were identically inaccurate to the fifth decimal digit.

SPSS and SAS performed most satisfactorily of all programs used. Both the regression coefficients and the corresponding test statistics for all twelve equations estimated using these packages were computed accurately, regardless of the machine used. The CDC machine with its software component appears to be the best suited of all machines tested to handle problems with ill-conditioned data matrices, regardless of the computer program.

There may be at least three reasons for the substantially different results obtained and summarized in table 2. First, the programs may in fact be different. Revised versions may be available at some locations but not at others. In addition, some programs may be designed to use "system" invert routines that are different at different locations. Second, the degree of single-precision computational accuracy for the machines is different; it is about seven decimal digits for the two IBM machines, about six for the Xerox machine, and about

[1] The concept of an "ill-conditioned matrix" centers on the expected severity of round-off errors generated in inversion. While many numbers have been proposed to measure the degree of ill-conditioning, empirical results have shown them to be inadequate (Ling). The interested reader is referred to Newman for a discussion of a commonly used measure, the P-condition.

[2] There are, of course, techniques (e.g., BMD5R Polynomial Regression) that can be used to fit a power series. Polynomials are chosen for this test because they are difficult to fit via least squares. The interested reader is referred to Beaton and Tukey for a good discussion of the problems encountered in the fitting of power series.

Table 2. Summary of Calculations for Equation (1) by Program and Machine

Program and Machine	Estimated Values for Regression Coefficients[a] β_0	β_1	β_2	β_3	β_4	β_5	R^2	S[b]
3MD2R[d]								
IBM1	109.68750	—	—	—	1.12573 (0)	0.99627 (0)	1.0000	0
CDC	1.68442	—	1.31578 (0.02164)[c]	0.96155 (0.00436)	1.00200 (0.00030)	0.99996 (0.00001)	1.0000	0.2277
IBM2	109.68750	—	—	—	1.12573 (0)	0.99627 (0)	1.0000	0
Σ_7[d]	−637.37500	—	—	9.63999 (0)	—	1.02904 (0)	1.0000	0
3MD3R								
IBM1	101009.12500	−1792.00000 [e]	928.00000 [e]	−112.00000 (18053.03125)	5.00000 (1001.10010)	0.81250 (19.90112)	0.9165	447902.75000
CDC	1.00099	0.99999 (38.31977)	1.00000 (12.63533)	1.00000 (1.64520)	1.00000 (0.09153)	1.00000 (0.00182)	1.0000	38.26454
IBM2	[b]	−1792.00000 (0)	1616.00000 (0)	−96.00000 (0)	7.00000 (0)	0.83203 (0)	1.0399	0
Σ_7[d]	—	—	—	—	—	—	—	—
TLS								
CDC	1.0000 (0.14419)	0.99997 (0.15834)	1.0000 (0.05221)	1.0000 (0.00680)	1.0000 (0.00038)	1.0000 (0.00001)	1.0000	0.02500
IBM2	1.0000 (964.4)	1.0000 (1059.0)	1.0000 (349.2)	1.0000 (45.47)	1.0000 (2.530)	1.0000 (0.0533)	1.0000	0.57892
SP								
IMB2	−510.0625	1097.86689 (319.11957)	−407.69507 (103.72288)	56.11794 (13.42815)	−2.08341 (0.74582)	1.06086 (0.01484)	0.99999	332.94214
MDVR1[d]								
Σ_7	−128.75000	307.67700 (0)	−121.05426 (0)	18.25566 (0)	—	1.02030 (0)	1.00000	0
MDVR2[d]								
Σ_7	−160.15883	351.15894 (0.02308)	−130.46193 (0.42195)	18.81564 (2.36353)	—	1.01980 (0.00205)	1.00000	423.48462

[a] The true values for all β's = 1.
[b] The true value of $S = 0$ and $R^2 = 1$.
[c] Estimated coefficient standard errors in parentheses. All reported calculations are rounded to five digits to the right of he decimal point unless program output printed fewer.
[d] The program failed to compute regression coefficients for all variables. Results shown are for the last step completed.
[e] Calculated value exceeded the maximum number of digits allowed in the program output format.

ifteen for the CDC.[3] Finally, the algorithms of arithmetic for the machines are different. Therefore, depending on the functions being performed and the data, different machines doing the identical calculation may generate numerical results that are different.

Although not reported, improved results were obtained, regardless of machine or software package, for equation (2). In those cases where all variables were included in the estimated equation, resulting parameter estimates were quite close to heir true values. This was not the case for equation 1). Either the estimated coefficients were quite close to their actual values, or they were seriously n error (table 2). Such a result may suggest that for nost problems encountered in research any of the nachines and programs tested could be expected to generate adequate results. There are cases in agricultural economics research, however, when ill-conditioned matrices are common. Consider demand equations that contain several interrelated product prices and some measure of income as independent variables and quantity (some large number?) as the dependent variable. In such cases, the results should be interpreted carefully and with due regard for the potential computational inaccuracies.

Certain programming inadequacies were also uncovered in this experiment. Although it is true that program users most often are not able to "correct" programmer inadequacies, it is important to recognize explicitly that programmers and machines do have important influences on the generation of the numerical estimates ultimately used for policy analysis. We discovered, for example, that least squares programmers often incorporate features that operate as "default" mechanisms permitting execution to continue even though an impossible calculation (e.g., dividing by zero) has been requested. Furthermore, such features tend to operate without messages to warn the user.

Finally, while some programs failed to complete the computations for these problems, this result should not necessarily be interpreted as a criticism of the package. If the program fails to solve, it should serve as a caveat to the researcher that there are possible data problems. In most instances we would argue that it is better to have no solution than one that is incorrect or meaningless.

[3] The degree of computational accuracy for a machine is specfied here as a function of bits per word. It is recognized that computational accuracy is also dependent upon the type of calculation as well as the range of data input.

Conclusions

The results of this research and others like it indicate that there is still considerable variation in computational accuracy among regression routines and computers. There is also variation in the computational accuracy of other statistics that are commonly reported by agricultural economists, e.g., coefficient standard errors, residual standard error(s), and R^2. Such results continue to stress the importance of knowing not only the nature of the problem and the data but also the limitations of available computational equipment and software. In short, the computational accuracy issue appears to be alive and well!

The previous discussion may well leave the applied researcher with a feeling of helplessness and it probably should! However, to gain an awareness of whether bogus results are being obtained when using least squares in applied economic research, the following simple precautionary steps can be taken. First, prior to use, computer programs should be tested for their ability to solve the test problems we have used here. This will indicate which programs at a given location are best capable of handling ill-conditioned problems and may help identify those with programmer errors. Second, parameters should be estimated using alternative routines prior to publication or use. Given the serious nature of the issue, perhaps the editor of our *Journal* should require authors to submit regression results from more than one computer program prior to accepting papers for publication. Third, calculations should be repeated using scaled, or otherwise adjusted, data. Adding a large constant to one or more of the variables and reestimating can highlight rounding error for many routines. The constant coefficient for the transformed problem will be different, but the estimated coefficient for all the variables will remain the same in the absence of rounding error. Finally, while it may be of little value for some routines, we suggest that the columns of the exogenous variables should be switched and the runs repeated. While theoretically the order of variable vectors in the $X'X$ matrix makes no difference, the computational method being used and the nature of the data may be such that switching column vectors prior to inversion will help the researcher identify data sets that are ill-conditioned.

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Transfer of Development Rights: An Analysis of a New Land Use Policy Tool: Comment

Leslie E. Small

In a recent article in this *Journal*, certain questions regarding the use of the transfer of development rights (TDR) mechanism in the vicinity of a specific highway interchange are investigated on an *ex post* basis (Barrows and Prenguber). The analysis focuses on the question of the characteristics of the development rights (DR) market that would be necessary "if restricted landowners were to be fully compensated" (p. 553). One of the conclusions is that "full compensation would have required widely fluctuating DR prices. Alternatively, stable DR prices would have meant that some owners would receive much more than full compensation and others less" (p. 556). On the surface, this would appear to be a serious flaw in the TDR mechanism. But the conclusion results from an unsatisfactory definition of "full compensation" and from a conceptually inadequate basis for the distribution of development rights. In this note I demonstrate that it is possible to achieve "just compensation," as defined by the courts, with stable DR prices.[1]

Barrows and Prenguber define full compensation as the "actual value *when sold for development* minus the agricultural value" (p. 554, emphasis added). Given this definition, they are correct in noting that the courts have ruled that full compensation is not required. In eminent domain cases, the courts must deal with the compensation question on an *ex ante* basis because there is no possible way to know what the actual price when sold for development would have been. Courts have consistently ruled that claims for compensation based on projections of what the land would have been worth for development some years hence can only be speculative in nature and are not compensable under the constitutional requirement of just compensation (Roettger). Lawyers and appraisers have developed a conceptually precise definition of just compensation as the difference between the market value of the property immediately prior to the taking and its market value immediately subsequent to the taking (Sando). In the case of the taking of development rights, this involves an assessment of the full market value (development value) of the land immediately prior to the imposition of the restriction on development and a separate assessment of the remaining use value (agricultural value in the case at hand) of the land at the time the restrictions are imposed.[2] The courts in effect have decided that the land market arrives at a general price level that best reflects the present value of expected future prices of land discounted for uncertainty regarding the nature and timing of the future development of a given area.[3]

Because the courts, acting in eminent domain cases, reject the concept of full compensation as defined by Barrows and Prenguber, the TDR mechanism can be analyzed more meaningfully by examining the characteristics of the DR market that would be necessary to provide the restricted landowner with just compensation. This approach is particularly appropriate because the TDR mechanism has been proposed as a possible alternative to the public acquisition of development rights through the use of the power of eminent domain (Rose, Woodbury).

The analysis of the relationship between just compensation and stable prices for DR is straightforward. With stable DR prices, just compensation could occur only if the initial distribution of DR among land parcels is in proportion to the "compensable value" (defined as the difference between market value and use value) of the parcels at the time at which the TDR program is initiated. In their analysis, Barrows and Prenguber allocate DR on the basis of the total assessed value of the land.

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[1] The term "stable prices" is used here to mean a pattern of prices over time such that the present value of the prices prevailing at any two points in time, discounted by the rate of interest appropriate for risk-free investments, is constant. With this definition of stable prices, the timing of the sale of a given landowner's DR has no effect on the present value of the amount he receives.

[2] Thus Barrows and Prenguber are somewhat misleading in their statement that "the courts have ruled that the full loss to the restricted landowner, i.e., the difference between the property's use value and development value, need not be compensated" (p. 551). This is correct only if development value is interpreted to mean the value that actually would have been received at some future point in time. If one interprets development value in the more usual way to mean current market value (reflecting development as the highest and best use), then the statement is incorrect.

[3] Barrows and Prenguber do calculate the present values of the prices required to meet their definition of full compensation, using a discount rate of 8%. But the resulting values are in no way comparable to the market value of the land immediately prior to the imposition of the TDR program. An *ex post* discounting of a known event is not the same as an *ex ante* discounting, through the market mechanism, of uncertain future events.

This approach, although perhaps dictated by the availability of data in the case study area, is conceptually deficient (and would lead to inequities among landowners) because it ignores the residual value of the land that remains with the landowner after he has sold his DR.[4]

In practice it is likely that any TDR program actually implemented is subject to challenges in the courts on the issue of compensation. The minimum requirements for a program to successfully withstand such challenges would probably be that an assessment of both market values and use values be made at the time that the TDR program is implemented, and that the DR be distributed to landowners in proportion to the difference between these values. Given this initial distribution of DR, one can conclude that price stability is a necessary condition for just compensation. Price stability alone is not sufficient because DR prices could be stable at a level either above or below that which would result in just compensation.

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[4] In a footnote, Barrows and Prenguber raise a separate issue of whether the assessed values to be used should reflect the market conditions before or after the location of the road is known. With the TDR mechanism being applied only in the vicinity of an interchange, it would be impossible to establish the program prior to knowing the location of the highway. It would thus appear that to meet the requirements of just compensation, the assessed market values would have to be based on the situation prevailing after the location of the highway was known.

In discussing the distribution of development rights, Barrows and Prenguber state that "a TDR program would require downzoning" (p. 554). This is incorrect. Downzoning suffers from the deficiency that it immediately worsens the position of the landowners in the development districts. With downzoning, these landowners would suddenly be required to purchase DR for permission to undertake the same development that had previously been permitted by the original zoning. An alternative is to use a form of upzoning in the development districts. Under this arrangement, the landowner would still be permitted to develop up to the original density limit without the purchase of DR. But if he were to purchase DR, he would then be permitted to develop to the new (higher) density limit.

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Transfer of Development Rights: An Analysis of a New Land Use Policy Tool: Reply

Richard L. Barrows and Bruce A. Prenguber

Transfer of development rights (TDR) has been subjected to considerable theoretical analysis since its recent introduction as a potential land use policy tool. In theory, TDR overcomes the problems of traditional zoning by ensuring compensation to restricted landowners through sale of development rights (DR). Landowners presumably cease to oppose restrictive zoning decisions, and TDR thus removes the economic incentive to thwart the community's land use plan. Compensation is the heart of TDR, and the critical issue is whether TDR results in compensation that is viewed as "fair" by both the courts and the community. Unfortunately, the issue is not as "straightforward" as Small suggests, and his proposal for development rights distribution would not mitigate the potential difficulties with TDR that we identified.

Small is incorrect when he argues that TDR must provide the owner with compensation equal to the difference between the market value immediately prior to the restriction and use value immediately after the restriction is imposed.[1] The level of compensation legally required of TDR depends on whether the courts view TDR as an exercise of the police power or the power of eminent domain. Further, if TDR is held to be a police power exercise, compensation legally required from DR sale depends on whether the preservation zone restrictions allow the owner a reasonable return on his property, as defined by the courts. Finally, the legal definition of just compensation may not be nearly as critical for TDR success as the notion of fair or just compensation held by members of the community. Each of these issues is explored in more detail.

If TDR is held to be a legitimate exercise of the police power and if the land use restriction in the preservation zone allows the landowner a "reasonable return" from use of his land, then legally no compensation is required from DR sale or any other source. The definition of reasonable return varies greatly but has generally been interpreted by the courts in terms of the reduction in property value with the imposition of the restriction (Large). Unfortunately, over eighty years of litigation has not resulted in any "conceptually precise" definition of the percentage by which market value must be reduced before a restriction is held to be a taking of property, requiring compensation under the Fifth Amendment (Sax, Large). A restriction that diminished the value of a property by 88% was held not to be a taking in a 1972 Massachusetts case, yet restrictions with much less effect on value have been declared an invalid exercise of the police power, a taking that requires compensation (Large). Since the definition of "taking" varies over time and space, very little can be said a priori about the relationship between stable DR prices and just compensation.

If a TDR program is held to be a police power regulation with no taking of property involved in the restrictions, then the DR market must meet only the community's definition for fair compensation. Ideas about what is fair certainly vary among groups and individuals in the community. Restricted landowners may argue that full compensation (difference between market or potential development value and restricted use value) should be provided by the DR market. Others may argue that because development values were created by the community growth, rather than individual action, no compensation is required (Costonis 1975). In order for the DR market to function smoothly, a TDR program must have the political support of the community because the DR market may be strongly influenced by expectations of future viability of the program and expectations of the likelihood of basic program changes by the local government.[2] Public support of a TDR program is partially determined by whether the public views as "just" the compensation available through DR sale. In the early years of a TDR program, there is little empirical evidence to judge its effectiveness in either guiding land use change or providing com-

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[1] In the original article, the question asked was "What price per DR would have to be paid to fully compensate each preservation district landowner? Full compensation is defined as actual value when sold for development minus the agricultural value" (p. 554). It was also noted that full compensation was not required by the courts, and that in the case study full compensation was not necessarily identical to market value minus use value immediately after program initiation.

[2] This aspect of TDR has not been fully explored and is a fruitful area for future research.

pensation to restricted owners. In these early years, the community's feeling about just compensation and whether DR sale provides it may strongly affect program performance. In the end, a TDR program that legally requires no compensation may fail miserably because the compensation provided through DR sale was not judged to be just by the community.

If TDR is held to be a legitimate police power policy, in the same manner as zoning, and if the preservation zone restriction reduces the economic return on the property to such an extent that it clearly constitutes a taking of property, or if there is a danger that the courts may hold the restriction to be a de facto taking, then the effectiveness of the TDR program hinges on DR prices and value. Conceptually, an exercise of the police power can legitimately and legally reduce property value up to some maximum. For discussion purposes, define "maximum restriction value" as the value of the property under the most stringent restriction that would be allowed by the courts under the police power. If the TDR preservation zone restriction reduces the property value to some level (termed "TDR value") below the maximum restriction value, then a "taking increment" may be defined as the difference between the TDR value and the maximum restriction value. Then the critical question is whether the courts view DR as a legitimate form of compensation and whether the potential value of the DR is held to compensate for the taking increment. If so, then the potential DR value tips the balance toward a court decision upholding TDR as a legitimate use of the police power that involves no taking of property. Thus, under this scenario, the legally required minimum DR price is that which yields the property owner a total DR value equal to the taking increment.

The definition of the taking increment is extremely imprecise because the maximum restriction value is not well defined, as noted above (Large; Sax; Bosselman, Callies, and Banta). TDR involves an element of reciprocity (DR in exchange for restrictions), and the courts have occasionally found reciprocity appealing in ruling on the taking issue (Costonis 1975). Finally, several researchers have argued strongly for a new legal-economic definition of taking under the Fifth Amendment (Bosselman, Callies, and Banta; Sax). Costonis has argued for a new power—the accommodation power—to supplement the police and eminent domain powers (1975). The accommodation power could be used by the courts when a stringent land use regulation is required for environmental protection, yet it is unfair by community standards and is a taking by legal standards. Under these circumstances, the courts or government could use the accommodation power to compensate the landowner, and the compensation would equal the taking increment defined above (Costonis 1976).[3]

The American Law Institute's model land development code also keys the award to the "minimum development necessary to eliminate the unconstitutional taking" (American Law Institute, Sec. 4-402(5)). While this accommodation power fits nicely with a TDR program, it must be emphasized that it is purely hypothetical at this time. Finally, the definition of legitimate police power exercise has been expanding recently (Bosselman, Callies, and Banta; Large). Equivalently, maximum restriction value has been declining, and TDR may freeze this evolution in the definition of property rights by guaranteeing landowners compensation for restrictions that may not require compensation in a few years' time (Barrows and Prenguber).

Alternatively, the courts may view TDR as an exercise of the power of eminent domain, requiring compensation to affected property owners.[4] It is significant that, in the only court cases to date involving TDR, the courts held that TDR was an exercise of the power of eminent domain ("The Unconstitutionality of Transferable Development Rights"). Each case involved the New York City program for landmark preservation and was unique in its specific detail and circumstances. While it is difficult to predict court decisions on TDR programs to guide land conversion on the urban fringe, the available evidence suggests that the courts may view TDR cautiously.

If TDR is an exercise of eminent domain, then the issue is whether DR constitutes just compensation, and the situation is again more complicated than Small suggests. The courts have developed a very complex set of principles for defining just compensation. One principle, as Small notes, is that the compensation must be commensurate with the dimunition in property value. However, it is misleading to argue that the definition of compensation value is "conceptually precise." In general, it is true that just compensation is defined as the difference between market value immediately prior to restriction and use value immediately after restriction. However, since the property in question has usually not been recently transferred on the market, its market value is not observed but is imputed by the courts. Estimation of market value is particularly troublesome when "market forces and public regulations are entwined" (Costonis 1975, p. 1042). The courts may (and sometimes do) take into account any existing or probable restrictions on the

[3] Costonis defines the taking increment as the difference between "reasonable beneficial use" (equivalent to our maximum restriction value) and resource protection use (equivalent to our TDR value) (1975, pp. 1049–55).

[4] It has been argued that TDR programs are likely to be classified as eminent domain because "reasonable return is often defined in terms of the return on other property similarly situated" ("The Unconstitutionality of Transferable Development Rights," p. 1107). TDR programs that allow normal agricultural activity in the preservation zone might fare better under the definition of "reasonable return" than programs for which open space is the only use of the preservation zone. Of course, if agricultural activity would meet the definition of reasonable return, then traditional zoning for the same purpose would also not involve a taking.

property, such as zoning, when determining compensable value (Costonis 1975).[5] The courts have on occasion allowed a potential market value, contingent on a zoning change and subsequent development, to be the standard for compensation in eminent domain cases (Large, Costonis 1975).

A second principle for defining just compensation, crucial for TDR, is that payment must be in money, must be unconditional, and the value of the payment must not be based on uncertain future events (Rose). The major conclusion of our analysis of the DR market in the highway interchange program was that full compensation (or some percentage of full compensation) would have required widely fluctuating DR prices.[6] Similarly, the DR market is not likely to deliver the compensation required by the courts under eminent domain or would do so only coincidentally. Significantly, in the two New York TDR court cases to date, the courts ruled that the DR distributed to restricted owners do not constitute just compensation because the value of the rights is uncertain, determined by what may be an "unpredictable market of the future" (New York Supplement, p. 765). Neither court decision held TDR unconstitutional, and each case was decided on the specific circumstances of the properties. However, it is likely that the basis of decision in these cases applies to any TDR program—that DR are not adequate as (eminent domain) compensation because the value of the rights will be determined in a market that may be unstable and which would only achieve just compensation by coincidence ("The Unconstitutionality of Transferable Development Rights"). This is also the conclusion of our economic analysis of the DR market, although our analysis was framed in terms of economic full compensation in the absence of a court decision defining just compensation in the interchange area.

Small also criticizes the method used to distribute DR and offers an alternative scheme. To date, there have been at least five different proposals for DR distribution: (*a*) proportional to acreage (Maryland Senate), (*b*) proportional to market value (Chavooshian and Norman), (*c*) proportional to assessed value (Rose), (*d*) proportional to the difference between market value and restricted value at the time the TDR program is initiated (New Jersey Assembly), and most recently (*e*) proportional to the difference between "maximum restricted value" as defined above and restricted value under TDR (Costonis 1975). We did not argue that any system was preferable but simply analyzed the two most widely suggested systems.

Thus, the acreage and assessed value systems were analyzed in our article, and it was found that there would be little difference in DR distribution between the systems. It is possible to use other systems for DR distribution, although no system is without its problems. Small defines compensable value as the difference between market value and use value at the time the TDR program is initiated. This definition may not correspond to the courts' definition, but this alternative for distributing DR is conceptually superior to some because it does recognize differences in restricted value under TDR. In the case of the highway interchange program, the distribution of DR would likely have changed little under this system because the parcels were quite uniform and had similar market and use values at the time of highway condemnation action. However, as we note, immediately after the highway is initiated, the market values would have increased, and differences among parcels may have emerged.

Finally, Small argues that TDR would not require downzoning. In theory, this is correct—TDR is conceptually complete with no mention of downzoning, and in our article we never argued that TDR always requires downzoning. However, we believe that in practice most TDR programs to control urban growth require downzoning in order to produce compensation for restricted landowners. Compensation requires a strong demand for DR (Rose, Barrows and Prenguber). Currently, many urban fringe areas are overzoned—more land is zoned for development than will ever be built up. In these areas the supply of developable land at existing allowable densities precludes strong incentives for DR purchase. Small's suggestion of upzoning would further overzone these areas and would further reduce incentives for DR purchase. If a TDR program is implemented with no downzoning (or with upzoning) in the development districts, it is quite possible that development may proceed far into the future with no DR purchase. Thus, in many areas, TDR would require downzoning to force DR purchase in order to compensate restricted landowners. Small is correct to note that downzoning worsens the position of the landowners in the development districts, and we have argued that this might result in political pressures that may lock TDR programs into existing zoning levels, with disastrous effects on the compensation provided to restricted landowners.

In summary, Small's main argument can be restated more correctly. (*a*) If TDR is viewed as an exercise of eminent domain; (*b*) if just compensation, as defined by the courts in TDR cases, turns out to be the difference between some market value of the property (as defined by the courts) and its value at the time of TDR initiation; (*c*) if DR are distributed proportionally to the difference between this market value and use value; and (*d*) if DR

[5] The courts have viewed with suspicion local governments that restrict a property through zoning and then seek to acquire the property under eminent domain and pay only the restricted value.

[6] Small notes that our definition of full compensation is unsatisfactory because it is not equivalent to the court's definition of just compensation. We also note this difficulty, and unfortunately Small's alternative definition is only accurate in eminent domain cases and then only in those in which the market value of the property is unambiguous, i.e., there is no land use change underway or planned for the near future and no zoning on other land use restrictions on the property (Roettger).

prices are stable, then there exists some DR price such that restricted landowners are justly compensated. It is not likely that assumptions (*a*) through (*c*) hold simultaneously, even more unlikely that DR prices are stable, and extremely unlikely that a stable DR price coincides with that required for the assumed level of just compensation. Thus, while the existence of some stable DR price that provides just compensation may be logically demonstrated given appropriate assumptions, the proportion is not terribly useful to economists or decision makers seeking to analyze or implement TDR policies.

Future research should analyze the likely economic consequences and incentives created by TDR and the effect of variations in administrative decisions and definitions on TDR costs and incentives. This type of research is appropriate for economists and is more useful in advancing our understanding of the economics of TDR than vague theoretical pronouncements of TDR's advantages. Significantly, the courts have not relied on arguments of the theoretical or logical consistency of TDR but have examined the issues arising from its application. Proponents of TDR would be well advised to do likewise, and economists can play a valuable role by analyzing the likely economic consequences of applying TDR to real-world situations. We believe that economists must conduct more empirical research to define and overcome the potential problems of the very promising concept of TDR. It would be tragic if TDR were discarded as a land use policy tool simply because programs were initiated without sufficient preliminary analysis to ensure success.

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Roettger, Gary J. "Just Compensation: Frustration of an Owner's Plans." *Appraisal J.* 39 (1971): 500–507.

Rose, Jerome G. "A Proposal for the Separation and Marketability of Development Rights as a Technique to Preserve Open Space." *Real Estate Law J.* 2 (1974): 635–63.

Sax, Joseph L. "Taking, Private Property, and Public Rights." *Yale Law J.* 81 (1971): 149–86.

"The Unconstitutionality of Transferable Development Rights." *Yale Law J.* 83 (1975): 1101–22.

Books Reviewed

Aresvik, Oddvar. ***The Agricultural Development of Jordan.*** **New York, Washington, and London: Praeger Publishers, 1976, xxviii + 375 pp., price unknown.**

To paraphrase the author, this book endeavors to present a fairly complete analysis of the structure and performance of the agricultural sector in the Hashemite Kingdom of Jordan since 1946 (p. vii). The contents cover most, if not all, of the traditional subjects one might expect in this type of book. Resources of land and water (chapter 6), main crops and forest products (chapter 8), livestock, poultry, fisheries (chapter 9), the range of policy issues (research, extension, and education), marketing, credit, land tenure, and special development problems (Jordan Valley development program) are all included. Probably too much information is provided for the reader, and some judicious pruning might have ameliorated some tedious sections. As a compendium of reasonably current information reflecting, in good part, the results of a 1974 symposium in Amman on Jordan agricultural development, this book is worth reading. It is a good introduction to the major issues facing the agricultural sector in Jordan.

There are difficulties with the book. Although it is a good source of basic information on the Jordan agricultural sector, it falls far short of being a reasonably complete analysis for that sector going back almost thirty years. It makes a valiant effort for the 1957–66 time period, but the major emphasis is on 1967–73. In view of the security problems in the Jordan Valley (over 40% of the sector's output) that precluded intensive cultivation and major rehabilitation efforts until 1970–71, it is difficult to criticize the book's deficiencies in this area. An honest effort was made to review the historical record of Jordanian agriculture. Unfortunately, the data base is not adequate to the task.

The list of problem areas in Jordanian agriculture, as outlined by the author, includes almost the entire text book list assignable to low-income, subsistence agricultural economies. Aresvik does not hide any of them. He is convinced that "The main agricultural problem is how to speed up the adoption of improved technology" (p. vii). As the final end point or cumulation of a series of other activities, he is probably correct. But what is lacking in the book is some effort to establish a priority system among the numerous issues facing the Jordanian agricultural sector. Land-tenure reform would appear to be a very high priority and the author probably would agree. Without placing tenant-shareholding arrangements on some legal contractual basis and providing greater equity, how will high-yield technology be adopted in the Jordan Valley, where 59% of the agricultural holdings are rented? Fragmentation of holdings falls in a similar category. Neglect of the small farm sector as to credit, inputs, etc., is another. As noted above, the list of issues is quite comprehensive. Not all are likely to be resolved in the future even with the best political intent and the continued high level of external financial assistance. So, are the Government of Jordan's priorities, if they exist on some measurable scale, correct or do they need to be revised?

This is an optimistic book. At times the reader is somewhat uncertain as to whether the text reflects the author's views or simply an uncritical acceptance of the contents of development plans put forward by the Jordanian government. Are Farmers Associations (pp. 316–17) really the key to the success of the Jordan Valley development program? Did they exist in fact when the book was being written? If not, what is the conceptual framework for their operation? If so, one minor question not mentioned in the text is who controls the Farmers Associations? How are decisions to be made and funds collected and allocated? This reviewer would consider that to be a critical issue to the numerous small farms owner-operated and tenant-sharecropper farmers in the Jordan Valley.

To repeat an earlier contention, I suggest that this book should be read by those interested in the problems and promises of the agricultural sector in Jordan. It contains a good source of basic information. In general, the analytical portions contain sound technical judgments and competent professional viewpoints. A more critical approach as to Jordanian agricultural planning and implementation (including the Government of Jordan's investment budgets) would improve the worth of the book. It does not, unfortunately, greatly assist the reader to reach "conclusions about strategies of agricultural development of general interest for poor countries and for agencies and organizations supporting such development" (p. viii). To what extent the book might help the Government of Jordan to refine its own agricultural development strategy remains to be seen.

Leonard G. Rosenberg
Agency for International Development

Emerson, M. Jarvin, and F. Charles Lamphear. ***Urban and Regional Economics: Structure and Change.*** **Boston: Allyn and Bacon, 1975, viii + 360 pp., $12.95.**

This book is intended for students who have completed only an introductory economics course and

is designed to serve as a text for an undergraduate first course in regional and urban economics. It is considerably different from the Prescott and Lewis book, which is more of a report on several regional research projects in which the authors were involved. The book by Prescott and Lewis appeals to a more advanced audience than does that by Emerson and Lamphear and might appear on the reading list for a graduate course rather than as the text for an undergraduate introductory course.

Emerson and Lamphear have written well and done an excellent job of introducing the field of regional-urban economics. The major fault, depending on the teaching philosophy of the introductory course instructor, may be that they attempted to cover too much material, thereby treating each subject only briefly. This approach is adequate for the instructor who, during lectures, substantially supplements the basic text, but the instructor who lectures straight from the text will find the treatment of each subject to be cursory.

Following a good, brief introductory chapter, chapter 2 introduces regional interindustry structures by describing the input-output technique in a very elementary fashion. Chapter 3 then uses input-output to describe how regional-urban performance can be monitored. The discussion may again be too brief, even for an introductory text.

A good basic discussion of location analysis, relating it to basic economic theory through the use of graphs, is contained in the fourth chapter. Chapter 5 extends the previous chapter through a discussion of spatial price competition, again very adequately relating the topic to basic economic theory.

In chapter 6 is a discussion of the theories of city-size distribution and the economies of central places. Chapter 7 discusses regional structures and growth including regional production functions; economic base, sector, and stages-of-growth theories; structural linkages; and shift-share and threshold analysis. These topics are well related to the previous discussion of input-output.

Chapter 8 concentrates on interregional trade through a discussion of gravity models, comparative advantage, and export-base theories, while chapter 9 discusses interregional factory flows including capital, labor, and technology.

The next two chapters present a descriptive and theoretical analysis of urban structure. The treatment is too brief for such a complex subject. The subject is poorly related to previously described location theory and interdependence analysis. The public economy of urban regions, including the theory of public goods and four forms of governmental intervention in the free-market economy, is discussed in chapter 12.

Chapters 13, 14, and 15 turn to a discussion of the functions and problems of urban governments including employment, housing, transportation, pollution, provision of services, and land use control. These chapters form a good, general discussion concentrating on externalities and the incidence of costs and benefits.

The concluding three chapters focus on both the problems of nonmetropolitan areas and experiences and prospects in new town and community development, and present a brief discussion of alternative regional and urban futures.

John W. Green
Economic Research Service
U.S. Department of Agriculture

Reference

Prescott, James R., and W. Cris Lewis. *Urban-Regional Economic Growth and Policy*. Ann Arbor, Mich.: Ann Arbor Science Publishers, 1975.

Bishay, Fahmi K. *Models for Spatial Agricultural Development Planning*. Rotterdam: Rotterdam University Press, 1974, xv + 172 pp., Dfl. 35.00.

Heady, Earl O., and Uma K. Srivastava, eds. *Spatial Sector Programming Models in Agriculture*. Ames: Iowa State University Press, 1975, xx + 484 pp., $12.95.

Bishay's book is the third volume in a series called Studies in Development and Planning, edited among others by H. C. Bos, director for the Center for Development Planning of the Netherland School of Economics, Erasmus University, Rotterdam. The first two dealt with the problems of economic integration and price consistency in development planning, respectively. The series consists of studies employing a quantitative approach to the methods and techniques of development planning. Bishay, a staff member at the Center, sets out to show how models, mainly linear programming ones, can be used to determine the optimum patterns of agricultural production in different regions, the corresponding domestic and international trade flows, and the agricultural investment plans in different space units.

After a brief introductory chapter that alludes to the many factors—soil, climate, seasonality, technology, management, institutions of tenure, and intersectional relationships, which make agricultural development a complex process to model, chapter 2 delineates the spatial dimensions. These include differences in production opportunities, transportation costs, and differences in regional objectives and interests.

A brief discussion of the Mennes, Tinbergen, and Waardenburg model of spatial development planning is introduced to serve as a starting point for the models that follow, but this is by no means clearly done. Models are classified as short run (where a fixed supply of regional and national resources are assumed) and long run (where productive capacities are increased through investment

programs). Chapter 4 develops some of these short-run models in which net revenues with output and input prices, evaluated at world market prices, are maximized subject to regional and national resource constraints. Export limitations and domestic and transportation costs are then introduced to provide extensions to the basic model. The reader will find the numerical applications in chapter 5 particularly useful along with the interpretation of the duals or simplex multipliers, as they are called here. The long-run models developed in chapter 6 extend the activity analysis to include land reclamation, livestock production, and regional and national investment in expanding production capacities, reclaiming land, and developing livestock quality. Appropriate constraints are introduced, too, in the form of upper bounds on regional and national agricultural investment funds and livestock intensification programs. Further extensions show how to include investment levels in target years, gestation delays, regional and national mobility of resources, and domestic and international transportation costs. Numerical specifications of these long-run models are provided in chapter 7 and again prove very useful. An appendix that shows the use of the semi-input-output methods to estimate the indirect effects of investment projects and another that looks at alternative formulations in relation to decentralized planning using decomposition techniques are also provided.

The Heady and Srivastava book essentially brings under one cover the work carried on by Heady and his associates over the past two decades in developing and applying programming models to look at the problems of production and spatial allocation in U.S. agriculture. Much of this work carried out at the Center for Agricultural and Rural Development, Iowa State University, has been previously available through the various USDA and Iowa State University technical bulletins as well as through articles in this journal. Here, it has been assembled in a manner that is designed to allow a progression from a simple prototype model of regional production and distribution to models that allow for the considerable detail through the inclusion of such factors as different agricultural technologies, transportation costs, domestic and export demand relationships, various pricing and other policy alternatives, income, and the measurement of employment and environmental impacts. Although an attempt is made to allow someone who is unfamiliar with this literature to progress from simple to more complex model structures, the variety of unspecified model variations prevents the book from achieving this purpose fully in spite of considerable expository detail.

There are altogether twelve chapters in the book, each devoted to a separate study or set of studies. Chapter 1, by Alvin C. Egbert and Earl O. Heady, summarizes three studies designed to determine the optimal regional location of wheat and feedgrain production in U.S. agriculture. A number of model variations are used to analyze the problem of deficit and surplus producing areas given the quantities required for consumption on a broad regional basis. Chapter 2, by E. O. Heady and N. K. Whittlesey, summarizes a study done by them that was used to determine the efficient interregional allocation of food and fiber production in the United States. This study extends the earlier work by including more homogeneous regions (144 spatially separated producing and 31 demand regions) and transfer and transportation activities. Chapter 3, by the same authors, extends their earlier study to analyze the relative costs of a variety of simulated land retirement programs by including regional land and crop quotas in the models. This policy issue was of considerable importance in U.S. agriculture in the late sixties, when this study was carried out. Chapter 4, by E. O. Heady and M. O. Skold, is a summary of a study that uses the same basic model developed in the Heady and Whittlesey studies (chapters 2 and 3) to 'project' the interregional shifts in grain production in the United States to 1975 by specifying conditions of technological improvements and demand growth associated with an increasing population. Feed requirements for livestock production as well as growth in exports were also incorporated in these models. Chapter 5, by R. F. Brokken and E. O. Heady, goes a step further by including the livestock sectors that had been excluded from previous studies by including some twenty livestock-producing and consuming areas. The model is used to look at interregional production and flows of wheat and feedgrain products along with those of livestock products. Chapter 6, by R. K. Eyvindson, E. O. Heady, and U. K. Srivastava, removes the simplifying assumptions of a single 'representative farm' for each region used in the earlier studies by incorporating farm size and additional land quality classes. The model results allow for the distribution of production between different farm size groups that may have different production efficiencies and resource constraints. Chapter 7, by H. C. Madsen, E. O. Heady, and K. J. Nicol, uses basically the same model developed by Skold and Heady (chapter 4) to estimate the projected trade-offs between different farm policies for 1975. Three separate price levels and a set of four government programs for land retirement are analyzed, and their effect on such factors as the level of farm incomes, costs of production, treasury costs, amount and location of land retired, and regional distribution of government payments are studied. Chapter 8, by S. T. Sonka and E. O. Heady, uses the same model to measure the economic impact of several types of farm programs on incomes and employment generated in rural areas and agriculturally related industries. The secondary impacts on income and employment are measured by using an input-output model of the U.S. economy to which the linear programming results on crop production and dis-

tribution are linked through changes in final demand. Chapter 9, by E. O. Heady, H. C. Madsen, K. J. Nicol, and S. H. Hargrove, is an application of a large-scale mathematical programming model to estimate the demand for land and water used in agriculture. This water demand-allocation model incorporates all major agricultural commodities, land resources for 223 agricultural-producing regions, and water resources for 51 water supply regions in the 17 western states and 27 consumer markets. Given relative yields, technologies, production and transport costs, and water requirements, the model estimates the comparative advantage in the allocation of land and water to competing uses. Further projections are made to 2000 to analyze water needs and irrigation developments in the context of an overall land use and agricultural policy. Chapter 10, by E. O. Heady, K. J. Nicol, and H. C. Madsen, uses the same model (chapter 9) by extending it to include some environmental impacts through environmental limits on chemical fertilizers, pesticides, livestock wastes, and soil losses. Chapter 11, by H. H. Hall, E. O. Heady, A. L. Stoecker, and V. A. Sposito, is a departure from the rest of the book in that it is devoted to a quadratic programming model of U.S. agriculture. After setting out some theoretical considerations relating to the use of nonlinear models to look at 'competitive equilibrium' and 'efficiency' (a section well worth reading in and of itself), the formulation and results of a spatial quadratic programming model are presented and compared with a similar linear model (chapter 5). Chapter 12, by J. A. Fedeler, E. O. Heady, and W. W. Koo, presents a regional linear programming model used to analyze a national and interregional grain transportation and production network.

The book is accompanied by a set of microfilms that contain all the data tables relating to the various chapters. Although this no doubt saves space, it is most frustrating for someone who wishes to examine these tables in greater detail while reading the book. Without access to a microfilm projector, these cannot even be viewed.

I found Bishay's book interesting as it takes agricultural development planning as its primary focus and treats it in both its national and international setting. I had hoped that this book could serve as a suitable textbook for a graduate course on the application of programming methods to problems of agricultural development. Unfortunately, I do not believe Bishay's book can serve this purpose although it presents some interesting ways of handling some important agricultural development problems in a programming context. The main reason for this is that although the models are clearly laid out, the numerical examples provided to illustrate their use are purely hypothetical. They never really confront the real world of development in the less developed countries (LDC's)—the data problems, the complexity of farm structure, the maze of policy and other interventions, the 'realism' of the assumptions, and the validity of the results. Even informal validation that requires a common sense judgment about the 'realism' of the results is not possible with hypothetical problems. The integration of investment activities and gestation lags in the long-run models presents enormous practical difficulties that remain concealed in a hypothetical exercise. In spite of these shortcomings, which reduce the credibility of the work among practitioners, the models explored here provide very useful ways of modeling spatial agriculture development as both the dynamic element of investments and the influence of the foreign sector are treated. One would hope that more real-world applications will follow from this work.

By contrast, the Heady and Srivastava book provides examples of modeling spatial agricultural development that are wholly credible because they are geared to real-world data, policies, and problems. Any practitioner can follow the model structure, see what data were needed to make the models operational, and evaluate the results for himself. The operational models turn out to be very large in size (the linear model in chapter 9 for example includes 5,426 activities and 3,220 equations) if they are to be used effectively for policy analysis. Models incorporating national and regional investment activities and agricultural exports and import limitations could very well be two to three times as large, a problem not addressed by hypothetical exercises.

The models proposed in both these books can presumably be used for policy analysis, but they raise questions, especially about the use of such models in LDC's, that need to be addressed further.

First, there is the critical problem of model validation. Statistical inference techniques as currently conceived are woefully inadequate for the purpose of validating complex sector models of the type currently being advanced for policy use. Even though validation is a more general concept than mere statistical inference, these books fail to address the issues squarely as do most practitioners using programming methods.

Second, to be useful in the agricultural sector, where a vast variety of heterogeneous units operate, a great deal of detail has to be incorporated, which makes applicable models very large. The associated data requirements and costs especially in terms of trained manpower make their use almost prohibitive in most developing countries, where research budgets, talent, and time are severely restrictive factors. Practitioners have to bring the effective costs of these methods down before they can become competitive with other more simple techniques.

Third, they are in general normative models and as such may have limited operational value in analyzing development problems. In specifying

what "ought" to be the spatial allocation of resources they fail to focus on what resource use actually is, how it came to be that way, and who, if anyone, will reallocate resources to conform to 'optimum patterns'.

Fourth, they are too aggregative for a sector that is known for its heterogeneity of response. These models almost seem to assume a 'central planning authority' that on the basis of known resources, technology, demand structures, transportation costs, and domestic and international prices allocates these resources optimally, provided it has the power to reallocate. But reality is different. In most cases these decisions are made by private farming units, and these allocate the resources in light of their own objectives and their own constraints and in response to their perceived economic opportunities. These models tell us nothing of how these decision units behave or respond to their environments. How do farmers, especially peasants in LDC's, perceive opportunities? What constraints do they face and what objectives do they have in mind? We know so little about these essential matters. Until and unless farm-level behavior is first understood and modeled, normative national models for the spatial allocation of agricultural resources provide few operational clues to the development of the agricultural sector, especially in LDC's.

Lastly, they do not yet provide an analysis of the richness of institutional structure and its constraints that may be crucial to the proper study of this sector. Imperfections in factor markets, tenure arrangements, factor immobility, discontinuities in investment decisions, and institutional rigidity are not treated, or when treated, only trivially.

In spite of these shortcomings the use of programming models to analyze a wide variety of issues in the agricultural sector is on the increase in both developed countries and less developed countries. These books provide useful guides to many aspects of this growing practice.

I. J. Singh
International Bank for Reconstruction and Development

Books Received

Amacher, Ryan C., Robert D. Tollison, and Thomas D. Willett. *The Economic Approach to Public Policy*. Ithaca, N.Y.: Cornell University Press, 1976, 528 pp., $18.50, $6.95 paper.

Berliner, Joseph S. *The Innovation Decision in Soviet Industry*. Cambridge: MIT Press, 1976, xii + 561 pp., $35.00.

Cochrane, Willard W., and Mary E. Ryan. *American Farm Policy, 1948–1973*. Minneapolis: University of Minnesota Press, 1976, xiv + 431 pp., $18.50.

Committee on Economics Teaching Material for Asian Universities. *Economic Theory and Practice in the Asian Setting, Volume 3: The Economics of Agriculture*. New York: Halsted Press, 1975, xii + 245 pp., $4.95.

Copeland, L. O. *Principles of Seed Science and Technology*. Minneapolis, Minn.: Burgess Publishing Co., 1976, xiv + 369 pp., price unknown.

Harper, W. James, and Carl W. Hall. *Dairy Technology and Engineering*. Westport, Conn.: AVI Publishing Co., 1976, viii + 631 pp., $43.00, $20.00 paper.

Heiser, Charles B. *The Sunflower*. Norman: University of Oklahoma Press, 1976, xxvi + 198 pp., $10.95.

Inter-American Development Bank. *Agricultural Policy: A Limiting Factor in the Development Process*. Proceedings of a seminar, 17–21 March 1975. Washington: Inter-American Development Bank, ix + 507 pp., price unknown.

International Rice Research Institute and Agricultural Development Council. *Bibliography on Socio-Economic Aspects of Asian Irrigation*. Singapore: Singapore University Press Pte Ltd, 1976, v + 80 pp., price unknown.

Organization for Economic Co-operation and Development. *Economics of Transfrontier Pollution*. Paris: OECD, 1976, 218 pp., $10.00.

Pennington, Jean A. *Dietary Nutrient Guide*. Westport, Conn: AVI Publishing Co., 1976, xi + 276 pp., $19.00.

Pomeranz, Y. *Advances in Cereal Science and Technology*. St. Paul, Minn.: American Association of Cereal Chemists, 1976, 418 pp., price unknown.

Regmi, Mahesh C. *Landownership in Nepal*. Berkeley: University of California Press, 1976, xvii + 252 pp., $15.00.

Ridgman, W. J. *Experimentation in Biology: An Introduction to Design and Analysis*. New York: Halsted Press, 1975, ix + 233 pp., $10.95.

Schwarz, Charles F., Edward C. Thor, and Gary H. Elsner. *Wildland Planning Glossary*. Berkeley, Calif.: Pacific Southwest Forest and Range Experiment Station, 1976, iv + 252 pp., price unknown.

Strachan, Harry W. *Family and Other Business Groups in Economic Development: The Case of Nicaragua*. New York: Praeger Publishers, 1976, xii + 129 pp., $15.00.

Tancer, Shoshana B. *Economic Nationalism in Latin America: The Quest for Economic Independence*. New York: Praeger Publishers, 1976, xiv + 251 pp., $21.50.

Upton, Martin. *Agricultural Production Economics and Resource-Use*. New York: Oxford University Press, 1976, x + 357 pp., $23.00.

News

Announcements

Nominating Committee

Kenneth R. Farrell, president of the American Agricultural Economics Association, has appointed the following persons to the nominating committee: James T. Bonnen, Michigan State University, Chairman; B. R. Eddleman, Mississippi State University; Glenn E. Heitz, Federal Land Bank of St. Louis; Darrell L. Hueth, University of Rhode Island; William T. Manley, AMA, U.S. Department of Agriculture; Richard J. McConnen, Montana State University; W. Neill Schaller, Farm Foundation; and J. B. Wycoff, Oregon State University. This committee will nominate two persons for the office of president-elect and two sets of two paired candidates for directors of the Association. Individual members of the Association should submit their suggested nominees to Jim Bonnen by 10 December 1976.

Erratum

A printer's error in "Do We Need a National Food Policy?" by H. S. Houthakker in the May 1976 issue of the *Journal* distorts the meaning of the fourth paragraph of the article. The first sentence of the fourth paragraph (p. 259) should read "It follows that the desirability of a National Widget Policy should be judged against two alternatives, one being abstention, and the other a set of contradictory measures."

ERS Bicentennial Year Lectures

Throughout 1976 the Economic Research Service has sponsored a series of Bicentennial Year Lectures to give a platform in the U.S. Department of Agriculture to some of our nation's most outstanding economists. Speakers in the first half of the year included Theodore Schultz, Irma Adelman, Charles E. Bishop, and Karl Fox. George Brandow, D. Gale Johnson, Maurice Kelso, and Earl Heady are scheduled for presentations in the fall. ERS expects to publish the lectures in single publication early next year.

AAEA Awards Program

Through its awards program the American Agricultural Economics Association recognizes professional excellence in several subfields of agricultural economics. The AAEA recognizes professional achievement at the student, the young professional, and the more experienced levels, in research, teaching, and extension activities. Sixteen awards will be presented in 1977.

The program has a rich tradition as can readily be noted by a review of the roster of award winners over the years. The AAEA believes that this tradition will be continued in the 1977 program.

The 1977 program has been organized and will be conducted by committees representing a substantial professional input of nearly 100 committee members. We hope you will submit nominations for the categories outlined in this announcement. The general awards chairman is A. Gordon Ball, College of Agriculture, University of Guelph, Guelph, Canada N1G 2W1.

Distinguished Extension Programs

The distinguished extension program awards recognize achievement of excellence in extension economics teaching programs. Two awards are offered in 1977. One award will be given to an individual with less than ten years experience in extension education, and the other award will go to an individual with ten or more years of experience in extension education.

Nomination. Nominations may be made by any member(s) of the AAEA and selection will be made from among those nominated. The nominee must have been active in extension teaching for at least one year at the time of the nomination, and the content of teaching efforts must be principally in the field of agricultural economics. Each nomination must be made by separate letter accompanied by eight copies of documentary evidence indicating nominee's name and extension title; extension program area in which teaching is conducted; identification of the clientele served; objectives of the educational program; teaching techniques, educational methods, and materials utilized; and effectiveness of the extension teaching effort in terms of clientele response and/or establishment of the utility of the extension teaching program.

Evaluation. Each nominee will be evaluated on the quality of work as indicated by the documentary evidence submitted with the nomination relative to the following characteristics: effectiveness in teaching application of economic principles and tools of analysis appropriate to the problem and audience involved; ability to conceptualize new extension educational programs and application of new teaching concepts to existing programs; effectiveness in bringing about significant behavioral change and/or understanding of clientele; and contribution to im-

proved extension teaching in agricultural economics as evidenced by participation in appropriate professional activities and organizations.

Due dates. Nominations and supporting evidence must be submitted by 1 February 1977 to the subcommittee chairman: Everett Peterson, Department of Agricultural Economics, University of Nebraska, Lincoln, Nebraska 68508. Recommendations of the subcommittee will be forwarded to the general awards chairman by 15 May 1977.

Distinguished Undergraduate Teaching

The distinguished undergraduate teaching awards recognize and encourage meritorious performance in undergraduate teaching in agricultural economics. Two awards will be given: one for an individual with less than ten years of experience as an undergraduate teacher, and one for an individual with ten or more years of experience as an undergraduate teacher.

Nomination. Nominations may be submitted by any member(s) of AAEA. Winners will be selected based entirely on the supportive material submitted. Renominations are invited providing the supporting evidence is updated and resubmitted. Nominees must be actively engaged in teaching at a professional level during the 1976–77 school year. Nominees must have demonstrated outstanding ability as an undergraduate teacher of agricultural economics. The format of the nomination material submitted should use as primary categories the five major criteria areas listed in the evaluation criteria section that follows. Include biographical data of the nominee—name, present position, education, and number of years of university-college teaching and experience in the profession. Supporting evidence must be limited to three pages for each of the five primary categories of the nomination. No more than three letters of reference from peers and students for each of the five primary categories should be included. Adjunct material may be included as an appendage to the nomination package if desired, for example, summaries of student class evaluations for courses taught. Eight copies of each nomination package are required.

Evaluation. Five major criteria areas will be used in evaluating nominations with relative weights as follows. (*a*) Quality of teaching (45%)—ability to motivate and stimulate student to learn (20%); innovation for presentation, evaluation measurements (15%); and mastery of subject, use and application to business conditions (10%). (*b*) Academic advising, counseling, and extracurricular activities of students (20%)—advising and counseling (14%); and catalyzing extracurricular activities of students, i.e., department clubs or organizations, student council or senate, student publications, convocations, seminars, community involvement (6%). (*c*) Campus participation in instructional, course, and curricular improvement efforts (15%)—department, college, and university-wide. (*d*) Professional improvement in teaching for benefit of self and peers (15%)—published textbooks, manuals, bulletins (5%); research papers related to improved teaching (5%); and participation in professional meetings and committees related to improved teaching and student activities (5%). (*e*) Department/college/university teaching awards (5%)—student association/alumni awards.

Due dates. Nominations and supporting evidence must be sent by 1 February 1977 to the chairman of the distinguished undergraduate teaching awards subcommittee: Richard W. Schermerhorn, Department of Agricultural Economics, University of Idaho, Moscow, Idaho 83843. Recommendations of the subcommittee will be forwarded to the general awards chairman by 15 May 1977.

Outstanding Master's Degree Program

The outstanding master's degree program awards have as their objective development of professional excellence by individuals pursuing master's degree programs in agricultural economics. Three awards are offered. A cash supplement of $250 accompanies each award.

Nomination. Any department engaged in training agricultural economists at the master's degree level may submit nominations. Entries must be submitted by the head of the department where the degree is earned. A department may submit one nomination for each fifteen master's degree candidates or fraction thereof presented to a graduate school faculty during the year. To determine the number of eligible candidates, departments should limit consideration to candidates who will receive a degree in agricultural economics and to candidates who have taken agricultural economics as a field of emphasis. Nominations should include thesis or other comparable documentation. Selection will be made from documentation approved in final form by the student's advisory committee during the calendar year 1976, provided the candidate has met all other formal requirements for the master's degree. A published thesis may be entered in both the published research and master's program classes but will be eligible for only one award. Although a published thesis is acceptable, a copy of the thesis as submitted to the graduate faculty should be sent whenever possible. Three copies of all nomination materials (i.e., thesis) are required to be sent to the committee chairman. All copies will be returned after reading by the judges.

Evaluation. Copies of evaluation criteria may be obtained from any member of the subcommittee.

Due dates. All nominations and documentation should be sent by 1 February 1977 to the chairman of the outstanding master's degree award subcommittee: Dale J. Menkhaus, Division of Agricultural Economics, University Station, P.O. Box 3354, University of Wyoming, Laramie, Wyoming 82071. Recommendations of the subcommittee will be forwarded to the general awards committee chairman by 15 May 1977.

Outstanding Doctoral Degree Program Award

The outstanding doctoral program awards are given in recognition of development of professional excellence for persons pursuing a doctoral program in agricultural economics. Three awards will be given in 1977. A cash supplement of $250 accompanies each award.

Nomination. Entries must be submitted by the head of the department where the thesis or comparable document was presented in partial fulfillment of requirements for a degree. A department may submit one nomination for each twelve doctoral candidates or fraction thereof presented in agricultural economics to a graduate school faculty during the year. To determine the number of eligible nominations, departments should limit consideration to candidates who received a degree in agricultural economics and to candidates who have taken agricultural economics as a field of emphasis. Selection will be made from theses (or comparable documents) approved in final form by the student's advisory committee during the calendar year 1976, provided the candidate has met all other formal requirements for the doctoral degree. A published thesis may be entered in both the published research and thesis categories but will be eligible for only one award. Although a published thesis is acceptable, a copy of the thesis as submitted to the graduate faculty should be sent whenever possible. Three copies of a thesis must be sent to the subcommittee chairman. All copies will be returned after they have been read by the judges.

Evaluation. Criteria for evaluation of nominations may be obtained from any member of the subcommittee.

Due dates. Nominations and supporting evidence should be sent by 1 February 1977 to the chairman of the outstanding doctoral thesis award subcommittee: Terrence F. Glover, Department of Economics, UMC 35, Utah State University, Logan, Utah 84322. Recommendations of the subcommittee will be forwarded to the general awards chairman by 15 May 1977.

Quality of Research Discovery

This and the following three awards are given to encourage excellence in publications in all areas of agricultural economics.

Rules. There are no requirements regarding the number of authors or professional experience. Nominations may be submitted by individuals, departments, or agencies. Nine copies of each publication should be submitted, unless expense for the individual is excessive. Return of the publications is not customary but can be requested. Nominations should be submitted for only one award in either the quality of research discovery or quality of communication category for 1976.

Nomination. A maximum of two awards are given. Entries must specify that the nomination is to be judged for the quality of research discovery. Entries must have been published in 1976.

Evaluation. The research must be a significant contribution to the field of knowledge in agricultural economics. The work should demonstrate excellence in research methodology and may deal with conceptualization of researchable problems as well as empirical verification.

Due dates. Entries should be sent by 1 February 1977 to the subcommittee chairman: Irving Dubov, Department of Agricultural Economics and Rural Sociology, University of Tennessee, Knoxville, Tennessee 37901. Recommendations of the subcommittee will be forwarded to the general awards chairman by 15 May 1977.

Quality of Communication

The rules pertaining to the award for quality of research discovery also apply to this award for quality of communication.

Nomination. A maximum of two awards will be given. Entries must specify that the entry is to be judged for its quality of communication. Entries must have been published in 1976.

Evaluation. Entries must demonstrate superior communication of concepts or knowledge in any subject matter area or professional specialization (i.e., research, teaching, or extension) in agricultural economics to a specified audience. If dealing with transmission of research findings, the publication need not contain the author's original research but should improve communication within the profession as well as between it and other professions.

Due dates. Entries should be forwarded by 1 February 1977 to the subcommittee chairman: Irving Dubov, Department of Agricultural Economics and Rural Sociology, University of Tennessee, Knoxville, Tennessee 37901. Recommendations of the committee will be forwarded to the general awards chairman by 15 May 1977.

Publication of Enduring Quality

One award is offered for a publication with a publication date during the fifteen-year period 1952–66. Entries are judged on the basis of the enduring quality of their contribution to the profession.

Eligible entries are articles in this *Journal* (during part of the period considered, the *Journal* was known as the *Journal of Farm Economics*) regardless of whether the authors are AAEA members, and also other publications by authors, one of whom was a member of the AAEA at the time of publication. Entries must be submitted by departments or other administrative units, by colleagues, or by the authors themselves. Publications receiving an award in any other category in previous years are eligible for this award.

Entries should be sent by 1 February 1977 to the subcommittee chairman: Vernon R. Eidman, Department of Agricultural Economics, University of Minnesota, Minneapolis, Minnesota 55455. Nine copies of the publication should accompany the entry. Recommendations will be forwarded to the general awards chairman by 15 May 1977.

Outstanding Journal Article

The editor and editorial council of the *Journal*, with the editor as chairman, will choose the outstanding article in the 1976 volume of the *Journal*.

AAEA Fellow

Nominations for AAEA Fellow should be sent to the secretary-treasurer, John C. Redman, University of Kentucky, Lexington, by 1 December 1976. Any living AAEA member may be nominated. Those submitting nominations should be prepared to submit upon request biographical information in support of the nominee.

General Recognition

Awards will be presented at the annual AAEA awards program during the annual meeting at San Diego, California, 31 July–3 August 1977. Winners will be identified in the annual meeting awards program brochure and in the December proceedings issue of the *Journal*.

Personnel

Agricultural Development Council

Appointments: Shao-er Ong, former council associate, Bangkok, Thailand, is with the Department of Agricultural Economics, Michigan State University, for one year; **Donald C. Taylor,** former council associate, Kuala Lumpur, Malaysia, is with the Department of Agricultural Economics, University of Wisconsin—Madison, for one year; **Keizo Tsuchiya,** formerly with the Department of Agricultural Economics, Kyushu University, Fukuoka, Japan, is a visiting professor in the Department of Economics, Thammasat University, Thailand, Oct. 1976–March 1977.

University of Arizona

Appointments: Jimmye S. Hillman, head of the department, is a member of the Technology Assessment and Pollution Control Advisory Committee of the Environmental Protection Agency; **Gerald E. Korzan,** formerly with the Ford Foundation, is a visiting professor.

University of Arkansas

Appointments: Dewitt Jones, Ph.D. University of Missouri, is an assistant professor; **Frank T. Plafcan,** M.S. University of Arkansas, and **Thomas G. Sawyer,** M.S. University of Arkansas, are county extension agents with the Cooperative Extension Service.

University of California, Berkeley

Appointment: Michael Yokell, former assistant professor, Washington State University, is a National Science Foundation energy-related postdoctoral fellow.

University of California, Davis

Appointment: B. Delworth Gardner, former head of the department, Utah State University, is a professor and the director of the Giannini Foundation of Agricultural Economics.
Leave: Harold O. Carter, professor, is on sabbatical leave at the International Institute for Applied Systems Analysis, Vienna, Austria, Sept. 1976–Aug. 1977.

Clemson University

Appointment: Dennis L. Thomas, Ph.D. Iowa State University, is an assistant professor in farm management and production economics.
Leave: James C. Hite, associate professor, is with the Office of Regulatory Economics and Policy, U.S. Department of Commerce, during 1976; **Kenneth J. Roberts,** assistant professor, is an associate program director grants management, National Sea Grants Program, Washington, until 30 June 1977.
Retirements: Lehman M. Bauknight, Jr., and **Hooper C. Spurlock** received emeritus titles as professor and associate professor, respectively, May 1976.
Honor: Lehman M. Bauknight, Jr., former professor, received the Algernon Sidney Sullivan Award for outstanding service in recognition of his contributions to undergraduate teaching.

University of Connecticut

Leave: W. Davis Folsom, Ph.D. candidate, is a visiting assistant professor at Clemson University, Marine Resources Center, Charleston, South Carolina.
Return: Raymond O. P. Farrish is back as head of the department after spending a year as visiting professor at the University of Arizona.

Cornell University

Appointment: George J. Michalopoulos, professor, Athens College of Agriculture, Greece, is a visiting fellow.
Honors: Richard D. Aplin, professor of marketing, received the Professor of Merit Award for 1976 for excellence in classroom teaching, advising, and contribution to undergraduate programs; **Joseph B. Bugliari,** professor of agriculture and business law, received a $500 Chancellor's Award of Excellence in teaching.

University of Delaware

Leave: William R. Latham, III, assistant professor, is a visiting assistant professor at Clemson University.

University of Florida

Appointments: Jong-Ying Lee is a research economist with the Florida Department of Citrus; **Kary**

Mathis is the director of the Florida Agricultural Market Research Center.
Return: James A. Niles is back from teaching at the Agribusiness Institute of the Graduate School of Business, University of Santa Clara.

University of Georgia

Appointment: William Otha Mizelle, Jr., Ph.D. Clemson University, is an extension marketing economist, stationed in Tifton.

University of Guelph

Leave: Willem van Vuuren is in Europe on a Canada Council Grant to undertake a comparative land use study for one year beginning in September.

University of Hawaii

Appointment: Bryan W. Begley is a research associate.
Leaves: Robert A. Anderson, associate professor, is on sabbatical leave at the Western Rural Development Center, Oregon State University, Aug. 1976–Jan. 1977; **Salvatore Comitini,** associate professor, is on sabbatical leave as Food and Agriculture Organization advisor to the Fisheries Development and Management Project, Government of Indonesia, through 1976; **Chennat Gopalakrishnan,** professor, is on sabbatical leave as research associate at the Institute of Marine and Coastal Studies, University of Southern California, Sept. 1976–Aug. 1977; **Perry F. Philipp,** professor, is on sabbatical leave through November.
Resignations: Bertrand Renaud, former associate agricultural economist, is with the World Bank; **J. Louis Williams,** former associate extension specialist, is at Morningside College, Sioux City, Iowa.
Retirement: Jack T. Ishida, former professor and extension specialist.

University of Illinois

Appointments: Rabel J. Burdge, is an associate professor; **Dennis M. Conley** is an assistant professor.

Iowa State University

Appointment: Ronald E. Deiter is an assistant professor in economics.

Kansas State University

Appointment: David G. Barton, former assistant professor, Cornell University, is an assistant professor of agribusiness management in economics.

Louisiana State University

Appointments: Adolpho Martinez, Ph.D. Louisiana State University, is a research associate; **Stephen D. Reiling,** Ph.D. Oregon State University, is an associate professor of rural and community development resource economics.

University of Maine

Appointments: Johannes Delphendahl, professor, is chairman of the Department of Agricultural and Resource Economics; **Kenneth E. Wing** is the dean of the College of Life Sciences and Agriculture and the director of the Experiment Station.

University of Maryland

Retirement: George Max Beal, professor of agricultural and resource economics.

Michigan State University

Appointments: Ronald Cotterill, Ph.D. University of Wisconsin, is an assistant professor in food and agriculture policy, effective 1 Jan.; **Don Mitchell,** Ph.D. Iowa State University, is an assistant professor in food and agriculture policy.
Leaves: John Allen is on sabbatical leave to work and study in Massachusetts; **Carl Eicher** is on sabbatical leave to study as a fellow at the Woodrow Wilson International Center for Scholars, Washington, for one year; **Stephen Harsh** is on sabbatical leave to study and write an undergraduate textbook.

University of Minnesota

Appointments: Nariciso R. Deomampo, chairman of the Department of Agricultural Economics, University of the Philippines, is a visiting professor, Aug. 1976–July 1977; **Donald R. Newell,** M.S. University of Minnesota, is a research specialist in applied regional economics; **Delane E. Welsch,** Ph.D. Michigan State University, is a professor in farm management.
Resignations: Surjit S. Sidhu, former assistant professor, is an economist at the International Fertilizer Development Center, Florence, Alabama; **Stephen J. Ziegler,** former research specialist, is an instructor at the Bemidji Area Vo-Tech Institute, Bemidji, Minnesota.
Retirement: Truman R. Nodland is a professor emeritus of agricultural and applied economics after thirty-nine years of service.

Mississippi State University

Appointment: W. Lanny Bateman, former assistant professor, University of Georgia, is an associate professor and associate economist in marketing.

University of Missouri

Appointment: Richard Kenneth Rudel, former associate professor, South Dakota State University, is an associate professor.

University of Nebraska

Appointment: Raymond J. Supalla, formerly at New Mexico State University, is an associate professor.

University of North Dakota

Appointment: Arlen Leholm, former research associate, North Dakota State University, is a research associate.

North Dakota State University

Return: Roger G. Johnson, professor, is back from the Agricultural Research Institute, Dublin, Ireland.

Oklahoma State University

Appointment: James E. Casey, Jr., former instructor, Texas A&M University, is an assistant professor in production economics; **John Ikerd** is an associate professor.

Pennsylvania State University

Appointments: Theodore Alter is an assistant professor in extension public finance; **Walter W. Haessel** is an associate professor of econometrics in agricultural marketing and prices; **Richard D. Rodefeld** is an assistant professor in sociology of agriculture.
Retirements: Clare A. Becker, former professor of co-op organization, has left after twenty-nine years of service; **Kenneth R. Bennett,** former professor of statistics and econometrics, has left after twenty-six years of service.

Purdue University

Appointments: Timothy Baker is in research and teaching in farm management; **James Binkley** is in research and teaching in marketing and transportation; **Joseph Donnermeyer** is in extension and research in rural sociology and community development; **Mahlong Lang** is in research and teaching in agricultural marketing.
Leave: W. David Downey is a visiting professor at the School of Business, Indiana University, Sept. 1976–Aug. 1977.
Return: Ramon B. Wilson, professor of marketing and policy.
Resignation: John F. Marten is the executive director of Top Farmers of America, Milwaukee, Wisconsin.
Honor: J. B. Kohlmeyer was awarded the honorary degree of Doctor of Agriculture, May 1976.

Southern Illinois University

Return: Vincent Cusumano, assistant professor of agricultural industries, is back from a two-year assignment at the University FAO/UNDP Project, Federal University of Santa Maria Rio Grande do Sul, Brazil.

University of Tennessee

Appointments: John M. Devine is an instructor; **Dan L. McLemore** is an associate professor; **Robert H. Orr** is an assistant professor in rural sociology.

Texas A&M University

Appointments: Ray Sammons, former assistant professor, University of Arizona, is an area-economist-management, stationed in Amarillo; **Merritt J. Taylor,** former research associate, New Mexico State University, is a lecturer in farm and ranch management.
Retirement: Harold B. Sorenson, former professor.

U.S. Department of Agriculture

Appointments: Louise Arthur is with the environmental studies staff, NRED; **Jeff V. Conopask,** Ph.D. Virginia Polytechnic Institute and State University, is with the ERS; **Tom Stucker,** formerly at the University of Illinois, is in Agricultural Policy Analysis, CED.
Appointments in EDD: Signard Nilson, Ph.D. Cornell University, is a research economist in the Manpower Studies Program Area; **J. Norman Ried,** formerly with the Illinois Legislative Intergovernmental Cooperation Commission, is a social science analyst with the State and Local Government Program Area.
Appointments in NEAD: William B. Back is a project leader for the assessment of technology in the

food and fiber systems; **Dave Watt,** Ph.D. Michigan State University, is with the Economic Projections and Analytical Systems Program Area, Michigan State University.
Reassignments: Rodney Kite, formerly with CED, is with the Forecasting Support Group, Foreign Development Division; **Theodore Moriak,** formerly with the Agricultural Policy Analysis Program Area, CED, is with the Office of Management and Finance, ERS; **Ted Thornton,** formerly at Iowa State University, is with the Technology and Innovation Program Area, NEAD.
Reassignments in CED: William D. Givan is with the Georgia State Extension Service; **Ronald A. Gustafson,** formerly in Davis, California, is in Washington.
Reassignments in NRED: Gregory Gustafson, formerly in Washington, is with the Resource Organization and Control, Corvallis, Oregon; **James Johnson,** formerly with CED, is in East Lansing, Michigan; **Duane Marquis,** formerly with Agricultural Policy Analysis Program Area, CED, is in Houston, Texas; **Norman Starler,** formerly with the State University of New York, Fredonia, is with the Environmental Studies Group.
Returns: Walter G. Heid, Jr., CED, is back after acting as a consultant under a Kansas State University-Agency for International Development contract in Ecuador; **Harold Stults,** NRED, is back after eighteen months as a natural resource planner with the Development Assistance Organization, Riyadh, Saudi Arabia.
Resignations: Robert Golden, formerly with the Forecasting Support Group, CED, is with the Commodity Futures Trading Commission, Washington; **William C. Motes,** former director, EDD, is a legislative assistant for agriculture for Senator Dick Clark and a designee to the Senate Agriculture Committee Staff.
Retirement: Kenneth E. Ogren, former agricultural attache, Foreign Agricultural Service.
Retirements in CED: Charles Nauheim; Jim Vermeer; Charles Wilmot.
Honor in NEAD: Earl Gavett was presented the USDA Superior Service Award for outstanding research leadership in energy conservation and end use in agriculture.

Utah State University

Appointment: Jay C. Andersen, professor, is head of the Department of Economics.

University of Vermont

Appointment: Neil H. Pelsue, Jr., former associate professor, University of Maine, is an associate professor.

Virginia Polytechnic Institute and State University

Appointment: Jerry W. Looney, M.S., J. D. University of Missouri, is an assistant professor.

Washington State University

Appointments: Ron Faas, formerly at Michigan State University, is an extension CRD specialist; **Scott Matulich,** formerly at University of California, Davis, and **Douglas Young,** formerly at Oregon State University, are assistant professors.
Resignation: Dirck Ditwiler is at Murdoch University, West Australia.
Honor: Wallace Rehberg received the R. M. Wade Award for Outstanding Teacher in the College of Agriculture.

University of Wisconsin

Appointments: Wilmer A. Dahl is an assistant professor in agri-business management; **William Dobson** is chairman of the department; **Albert Nyberg,** on leave from the Rockefeller Foundation, is a visiting scholar; **H. Adedunmda Oluwasanmi,** vice chancellor, University of Ile-Ife, Nigeria, is a visiting professor, March–Aug.; **Russell Parker,** on leave from the Federal Trade Commission, is a visiting professor, May 1976–Oct. 1977; **Richard N. Weigle** is on the Agriculture Committee of the U.S. Chamber of Commerce, 1976–77.
Honor: Glen Pulver was elected president of the Community Development Society, 1977–78.

Other Appointments

Amir H. Baharuddin, Ph.D. University of Missouri, is an assistant professor at the School of Comparative Social Sciences, University of Sains, Minden, Penang, Malaysia.
Siddanaic Bisaliah, Ph.D. University of Minnesota, is with the Department of Sociology and Economics, University of Agricultural Sciences, Hebbal, Bangalore, Karnataka State, India.
James Bracht, M.S. University of Missouri, is a management trainee with the First National Bank and Trust Co., Joplin, Missouri.
Noel Devisch, Ph.D. University of Missouri, is a research economist with the Ministry of Agriculture, Belgium.
Harold L. Dickherber, M.S. University of Missouri, is with the U.S. Agency for International Development, Washington.
Rachel Doyle, Ph.D. University of Arkansas, is teaching at the College of Charleston, South Carolina.
J. Michael Gorham, Ph.D. University of Wisconsin,

is with the research department of the San Francisco Federal Reserve Bank.

Leonardo Green, M.S. University of Missouri, is the head of the Division of Project Evaluation, Ministry of Agriculture, Managua, Nicaragua.

Waldo Hooker, M.S. University of Missouri, is the head of the Production Economics Division, Ministry of Agriculture, Managua, Nicaragua.

Samuel W. McClure, M.S. University of Missouri, is a credit analyst for the Bank for Cooperatives, Omaha, Nebraska.

Stephen F. Mathis, M.S. University of Missouri, is a loan supervisor at Farmland Industries, Kansas City, Missouri.

Srilaorkul Somchai, M.S. University of Missouri, is an economist with the Division of Planning, Ministry of Agriculture, Thailand.

Alberto Valdés, formerly at the Centro Internacional de Agricultura Tropical, Cali, Columbia, is a research fellow at the International Food Policy Research Institute, Washington.

Billy R. Wynn, M.S. University of Arkansas, is a trainee with Arkansas Production Credit Associations.

Obituaries

Joseph Ackerman

Joseph Ackerman, former managing director of the Farm Foundation, died 3 May 1976 in Elmhurst, Illinois. Joe was a major force in the profession of agricultural economics, domestically and internationally for over three decades. Born on 20 July 1904 in Illinois, he received a B.S. in 1929, an M.S. in 1930, and a Ph.D. in 1938 from the University of Illinois. His professional life was intimately concerned with improving the effectiveness of agricultural economics extension, research, and teaching at all levels.

He worked as a professional farm manager after completing his M.S. degree, then spent a year in 1931–32 at Harvard on a research fellowship in agricultural economics. For much of the period up to 1939 he worked in Farm Management extension at the University of Illinois.

He joined the staff of the Farm Foundation in 1939, becoming managing director in 1955. Under his leadership the Foundation played a role almost without parallel in advancing agricultural economics through sponsorship of regional committees, seminars, and studies, as well as encouragement to the professional development of younger agricultural economists.

Ackermen filled many posts, undertaking every task with characteristic enthusiasm and energy. He served the American Farm Economic Association as vice president in 1949–50 and as president in 1954–55. He was constantly at the elbow of the organization, assisting it in numerous ways.

As secretary-treasurer of the International Association of Agricultural Economists, 1955–73, he played a key role in organizing and conducting its triennial conferences and in helping to insure its continuing effectiveness. He provided leadership in revitalizing the American Country Life Association in the postwar years, serving as president of the organization in 1947 and 1948, and was also the national president of Farm House Fraternity from 1948 to 1952. He was secretary-treasurer of the American Society of Farm Management and Rural Appraisers from 1939 to 1944. He participated actively in school affairs as a board member and officer at the local, state, and national levels. He served as president of the National School Board Association from 1966–67.

Ackerman was named a fellow of the American Agricultural Economics Association in 1964. His efforts in expending leadership training opportunities for extension personnel and in strengthening extension work in agricultural economics led to recognition in 1959 by Epsilon Sigma Phi, national honorary extension fraternity, for outstanding service to extension.

He is coauthor of the books, *Town and Country Churches* and *Family Farming*, and coeditor of two books, *Family Farm Policy* and *Agrarian Reform and Moral Responsibility*.

After retirement from the Farm Foundation, he spent three years with the Ford Foundation in New Delhi, India, applying the experience he had built up in the United States. On his return from India, he served the American Agricultural Economics Association as director of the National Employment Registry for Agricultural Economists.

His death brings sorrow to his many friends in the profession.

Glenn W. Hedlund

Glenn W. "Swede" Hedlund died on 24 June 1976 at age 67 following a brief illness. He had joined the staff of the New York State College of Agriculture and Life Sciences in 1933 and was associated with Cornell until retirement in 1974 except for five years, 1941–46, when he was professor and head of the Department of Agricultural Economics and Rural Sociology at Pennsylvania State University. During sixteen of the thirty-one years that he spent on the Cornell faculty, he was head of the Department of Agricultural Economics.

Hedlund received his B.S. degree from the University of Nebraska in 1930 and his Ph.D. from Cornell University in 1936. Reared on a wheat farm in Nebraska he had a deep interest in extension education essential to the growth and development of agriculture. At Cornell his teaching responsibilities were focused on agricultural cooperatives, farm finance, and marketing.

Hedlund's positive influence on agricultural cooperatives was one of his most important professional contributions. Over four decades his leadership directed cooperatives toward improved business management and was of importance in building the strong cooperative institutions that serve the agricultural economy. Instrumental in the formation of the New York State Council of Farmer Cooperatives, he provided program leadership for the organization from its inception. He served both as secretary of the Council during most of its existence until his retirement in 1974 and as a trustee of the American Institute of Cooperation for some years.

Hedlund served mankind and Cornell in many ways, acquiring an understanding of people, situations, and conditions far beyond the Cornell community. As an agricultural economist on the faculty of the University of Nanking, China, during 1936–

37, he traveled in the Near and Far East. Over the next sixteen years, Hedlund served on various committees, engaged in studying the agriculture of Bermuda for the Bermuda Government in 1939, studying and reporting on the organization and operation of the Farm Credit System for the Farm Credit Administration in the 1940s, and acting as chairman of a group studying cooperatives in relation to the Milk Marketing Orders during 1952–53.

During the academic year 1956–57, Hedlund worked on the University of the Philippines-Cornell contract toward the rehabilitation of the College of Agriculture at Los Banos. He served as chairman of Governor Nelson Rockefeller's Committee on Milk Marketing from 1961 until 1964, when he became a consultant for the Ford Foundation relative to education for employees of cooperatives in India. His sabbatical leave in 1972 was spent lecturing, consulting for the Agricultural Development Fund of Iran, and traveling in Europe and the mid-East. In the fall of 1975, Hedlund served as a member of a five-man team requested by the government of Bangladesh to evaluate the plant protection program of that country.

In 1953, Hedlund was cited by the Farm Credit Banks of the Northeast for his "outstanding service to agriculture in the Northeast." Upon his retirement from Cornell, the cooperative organizations concerned with agriculture in New York State initiated the establishment of the "Glenn W. Hedlund Scholarship Fund" in recognition of his contributions to agriculture in the state and nation.

Hedlund is survived by his wife Helen Howard Hedlund of Ithaca, N.Y., a son James Howard, two daughters, Mrs. John (Jean) Sullivan, and Mrs. Peter (Mary Beth) Marks, and three grandchildren.

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Martin A. Abrahamsen, University of Maryland

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Food Policy for America
Harold G. Halcrow, University of Illinois, Urbana-Champaign

Offering a comprehensive yet specific analysis of food policy for the United States, this book outlines the costs and benefits associated with various food policies. Emphasis is on choices to be made in the future in regard to food pricing and trade, farmland use and development, national credit programs, taxation, farm labor, rural development, and nutrition policy. Chapter summaries, suggested readings, questions, and a bibliography are provided. Available January, 1977, 480 pages, $19.50 (tentative).

Market and Price Analysis
Dale C. Dahl and Jerome W. Hammond, both of the University of Minnesota

A comprehensive, analytic treatment of agricultural price analysis, marketing, and distribution. The authors concentrate on fundamental economic structures and methods of analysis, covering the entire web of interrelated industries that make up the food and fiber sector of the economy. Topics include analytic tools; the principles on consumption, demand, and supply; market information and market and price policy; and economic development. Available January, 1977, 448 pages, $13.95 (tentative).

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1976. 210 pp., ill. $11.95. Order No. 1840–0

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olume 58 Number 5

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Senior Vice President and Fellow of Resources for the Future, Inc.
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Distinguished Professor Award, Oregon State University, 1970.
President, American Agricultural Economics Association, 1972–73.
AAEA awards for excellence in published research, 1972 and 1973.
President, Western Farm Economics Association, 1962–63.

Emery N. Castle has achieved recognition from colleagues for his teaching, research, administration, public service activities, and for his leadership in natural resource economics and farm management. To those who have been privileged to be closely associated with him, his distinction lies not in what he has achieved as conventionally measured but in what he is—a man infinitely concerned with the intellectual and personal development of those with whom he works.

Born in Kansas in 1923, he completed a B.S. and an M.S. in agricultural economics at Kansas State University and a Ph.D. degree at Iowa State University (1952). He served for two years as an agricultural economist with the Federal Reserve Bank of Kansas City. In 1954, he joined the agricultural economics faculty at Oregon State University, where he distinguished himself as teacher, researcher, administrator, and public servant. While there Castle served first as dean of faculty, then as head of the Department of Agricultural Economics, and finally as dean of the Graduate School. He also was a member of the Presidential Committee on University Goals and served for a decade on the State Water Resources Board of Oregon and its successor agency, the Water Policy Review Board of Oregon. He and his associates in the Department of Agricultural and Resource Economics pioneered investigations, often with other disciplines, in environmental quality, marine resources, and outdoor recreation.

Emery Castle served his profession well and often, acting as president of the Western Farm Economics Association, vice-president and later president of the American Agricultural Economics Association, and serving on the editorial board of *Land Economics*. He was

the first chairman of the AAEA consolidated awards program and served for three years in that capacity. The excellence of his contributions was recognized through awards such as Oregon State University's Distinguished Professor Award, the AAEA's Award for Excellence in Published Research, and Kansas State University's Distinguished Service Award in Agriculture.

Since January 1976, Castle has been vice-president and senior fellow of Resources for the Future. In this capacity, he continues his dedicated service to individuals, the profession, and as a leader in agricultural and natural resource economics.

Arthur T. Mosher

1976 Fellow

President, Agricultural Development Council, 1967–73.
Member of the Consultative Group on International Agricultural Research, Advisory Panel on the Future of the International Agricultural Institutes.
Visiting Professor, University of Chicago, 1953–55, and Cornell University, 1955–57.
Author, *Technical Cooperation in Latin American Agriculture*, *Getting Agriculture Moving*, *To Create a Modern Agriculture*, and *Serving Agriculture as an Administrator*.

Arthur T. Mosher is one of the agricultural economics profession's pioneers in international economic development. He entered this arena forty-three years ago when few American agricultural economists were concerned with the developing world and has devoted most of his professional career to service in the field of international development, playing a major role in institutionalizing an international development dimension in the education of agricultural economists and other rural social scientists, both in the United States and abroad.

Mosher was born in Iowa in 1910, receiving his B.S. in general agriculture and his M.S. in agricultural economics (1941) from the University of Illinois and his Ph.D. in economics from the University of Chicago (1946).

He joined the staff of Allahabad Agricultural Institute in India as an instructor in agricultural engineering in 1933. In 1938–39, he lived with his wife and son in an Indian village, renting an eight-acre farm and farming it by prevailing village methods to gain experience in Indian agriculture. After finishing his graduate studies in economics, he designed and managed a three-year experimental program covering 400 villages to test extension methods and materials. His attention was directed to the agricultural development problems of Latin America while serving as a visiting research professor at the University of Chicago (1953–55).

Mosher has been with the Agricultural Development Council since 1957, serving as president from 1967 to 1973. Under his leadership, the Council has had a key role in supporting advanced education of rural social scientists from Asia and in strengthening professional relationships between rural social scientists in the developed and developing countries.

While his writings are directed primarily to

development practitioners, his publications have exerted a deep impact on both thought and practice in the field of agricultural development. His book, *Technical Cooperation in Latin American Agriculture;* monographs, *Getting Agriculture Moving, Creating a Progressive Rural Structure, To Create a Modern Agriculture, Serving Agriculture as an Administrator,* and bulletin, *Varieties of Extension Education and Community Development,* are included among his major publications.

This servant of international agriculture has found time to act as visiting professor of comparative extension education at Cornell University, panel member on world food supply for the President's Science Advisory Council, member of the Research Advisory Committee for the Agency for International Development, and member of the Consultative Group on International Agricultural Research, Advisory Panel on the Future of the International Agricultural Institutes. He continues to serve with the Agricultural Development Council in Asia where he began his distinguished career.

Willard F. Mueller

1976 Fellow

William F. Vilas Research Professor of Agricultural Economics, professor of economics, professor in the Law School, University of Wisconsin, 1969–present.
Chairman, Department of Agricultural Economics, University of Wisconsin, 1970–72.
Executive Director, President's Cabinet Committee on Price Stability, 1968–69.
Chief Economist and Director, Bureau of Economics, Federal Trade Commission, 1961–68.
Chief Economist, Select Committee on Small Business, House of Representatives, U.S. Congress, 1961.
President, Association for Evolutionary Economics, 1974.

Willard F. Mueller has achieved an international reputation as teacher, researcher, economic advisor, and public policy administrator. He has the unique ability to identify emerging problems and to incorporate successfully economic knowledge into workable public policies. While serving as chief economist of the Federal Trade Commission, he contributed to such innovative policies as developing merger guidelines in several food and other industries, creating the FTC's premerger notification program, and implementing affirmative disclosure requirements in advertising. His fierce intellectual independence coupled with an outstanding sense of fair play have created an ever widening demand for his counsel among public policy makers in agriculture, consumer affairs, business, the state government of Wisconsin, Congress, and the Executive Office of the President. Friends and adversaries agree that Mueller is unintimidated by special interests, unafraid of controversial issues, and dedicated to making the American economic system perform justly as well as efficiently.

Mueller's academic writings of 1959–61 and his collaborative work with colleagues and fellow researchers from the North Central region led to the subsequent adoption by agricultural economists of industrial organization theory as a framework for research. As chairman of the North Central Regional Research Committee, Organization and Control of the U.S. Food Production and Distribution System, he and his colleagues developed a highly innovative approach to regional research that has received wide support from state experiment stations, the U.S. Department of Agriculture, and congressional committees.

Born on a farm in western Minnesota, Mueller served in the Navy in World War II, received a B.S. in economics (1950) and an M.S. in agricultural economics (1951) from the University of Wisconsin, and a Ph.D. in economics from Vanderbilt University (1955). In addition to teaching at the University of

California, Davis, and the University of Wisconsin, Mueller has taught at the American University, University of Maryland, and as a visiting professor at Michigan State University. During 1958–59 he was associate editor of the *Journal of Farm Economics* and currently is on the editorial advisory board of the *Industrial Organization Review*. In 1973 he was vice-president and in 1974 president of the Association for Evolutionary Economics, an association of institutionalist-oriented economists.

Since returning to Wisconsin in 1969, Mueller has taught in the departments of agricultural economics and economics, as well as in the Law School. He has an ambitious research program with a large number of outstanding graduate students. In addition to numerous professional articles and several books, he includes among his most recent publications two extensive research monographs on multinational corporations prepared with his students for the Subcommittee on Multinational Corporations of the Foreign Relations Committee, U.S. Senate.

Mueller is also active in community affairs, particularly in working to enhance the opportunities of mentally retarded citizens.

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Harcourt A. Morgan

1917
Henry W. Jeffers

1918
George A. Billings

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John R. Fain

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Henry C. Taylor

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Walter F. Handschin

1922
Benjamin H. Hibbard

1923
Thomas P. Cooper

1924
Edwin G. Nourse

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Milburn L. Wilson

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Thomas N. Carver

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John I. Falconer

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Lewis C. Gray

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H. E. Erdman

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Harold C. M. Case

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Oscar C. Stine

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John D. Black

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Howard R. Tolley

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William I. Myers

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Waldo E. Grimes

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Joseph S. Davis

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Oscar B. Jesness

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Ernest C. Young

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Irving G. Davis
Foster F. Elliott

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Hugh B. Price

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Murray R. Benedict

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George S. Wehrwein

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Sherman E. Johnson

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Eric Englund

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Lawrence J. Norton

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Frederick V. Waugh

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Asher Hobson

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William G. Murray

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Oris V. Wells

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Warren C. Waite

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Forrest F. Hill

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George H. Aull

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Harry R. Wellman

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Thomas K. Cowden

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Joseph Ackerman

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Karl Brandt

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H. Brooks James

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Harry C. Trelogan

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Raymond G. Bressler, Jr.

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Willard W. Cochrane

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William H. Nicholls

1962
Bushrod W. Allin

1963
George E. Brandow

1964
Lowell S. Hardin

1965
D. Gale Johnson

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Kenneth L. Bachman

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Lawrence W. Witt

1968
C. E. Bishop

1969
Harold F. Breimyer

1970
Dale E. Hathaway

1971
Jimmye S. Hillman

1972
Vernon W. Ruttan

1973
Emery N. Castle

1974
Kenneth R. Tefertiller

1975
James Nielson

1976
James T. Bonnen

1977
Kenneth R. Farrell

Kenneth R. Farrell

1976–77 President

Deputy Administrator, Economic Research Service, U.S. Department of Agriculture, Washington, D.C., 1971–present.
Associate Director and Economist, Giannini Foundation of Agricultural Economics, University of California, Berkeley, 1969–71.
Director, American Agricultural Economics Association, 1972–74.
Member, International Association of Agricultural Economists; American Agricultural Economics Association; American Economic Association; American Association for Advancement of Science.

Kenneth R. Farrell was born in a rural community near Ottawa, Canada. As an undergraduate majoring in agricultural economics at the Ontario Agricultural College, Guelph, he was a member of several varsity sport teams and public speaking and debating teams of the College, receiving a B.S.A. with honors in 1950.

Following graduation, he spent two years in North Dakota as an agricultural instructor in a veteran's rehabilitation program. In 1953 he entered Iowa State University, Ames, where he received an M.S. and a Ph.D. in agricultural economics.

Farrell joined the staff of the Giannini Foundation of Agricultural Economics, Agricultural Extension Service, and the Department of Agricultural Economics, University of California, Berkeley in 1957, serving in various administrative, research, resident instruction, and extension posts including those of assistant director, Agricultural Extension Service; special assistant to the Dean of Agriculture; and associate director, Giannini Foundation. He was Fulbright Lecturer in Agricultural Economics at the University of Naples, Italy. The next four years were spent on leave from the University, first to the National Commission on Food Marketing to conduct a study of agricultural marketing order and agreement programs and then to the Economic Research Service, U.S. Department of Agriculture, where he served as director of the Marketing Economics Division and later as assistant administrator and chairman of the Outlook and Situation Board.

An author of numerous publications primarily in the fields of marketing, policy, and trade, Farrell has served as consultant to public and private organizations in the United States and

abroad. In addition to his present duties, he is the chairman of the Social and Behavioral Sciences Committee, USDA Graduate School; cochairman of the North Central Research Planning Committee; and chairman of the U.S.-Spain Project in Agricultural Economics, NSF-USDA. He has been active in the AAEA throughout his career, serving on various committees, the Editorial Council, and on the Executive Board as director and president-elect.

He, his wife Mary, and their youngest child reside in Reston, Virginia. He is an ardent gardener and golfer. He and his wife are active in local community affairs, church, and social action organizations.

Public Policy, The Public Interest, and Agricultural Economics

Kenneth R. Farrell

This is a particularly appropriate year for review of agricultural economics in relation to public policy. The quadrennial presidential election heightens our perceptions of major national public policy issues and the governmental process. It is a year of economic recovery and comparative stability, affording an opportunity to reflect upon the turbulent events of the past four years and longer-term economic and food policy issues. It is a year that foreshadows public debate on new farm commodity price legislation.

It also is a year of two bicentennials—the Declaration of Independence and the publication of the *Wealth of Nations*. The Declaration of Independence and the Bill of Rights set forth egalitarian social and political goals based upon principles of individual freedom, human dignity, and equality. Throughout the evolution of our society, from Jefferson's agrarian democracy to our current complex, industrial democracy, those principles have continued to influence pervasively the nature of national public goals and policies.

Smith's treatise expounded a self-regulating, open market economy in which social welfare was maximized by individual pursuit of economic self-interest. That treatise, later elaborated as a theory of perfect competition, provided a philosophic foundation for our capitalist market economy. It, too, has left a large imprint on national goals and policies.

But as we sometimes overlook, the *Wealth of Nations* was not written in the vein of narrow economic determinism. It was written in the tradition of political economy, incorporating philosophical and moral values compatible in many respects with the principles of our Declaration of Independence. That balance between philosophical and moral values that attain political status on the one hand and outcomes of a market economy on the other is at the heart of major public policy issues of our times. The late Kermit Gordon phrased the issue as follows: "Contemporary American society is, in a sense, a split-level structure. Its political and social institutions provide universally distributed rights and privileges that proclaim the equality of all citizens. But its economic institutions rely on market-determined incomes that generate substantial disparities among citizens in living standards and material welfare. . . . The resulting mixture of equal rights and unequal incomes creates tensions between the political principles of democracy and the economic principles of capitalism" (Okun, p. vii). Therein is the genesis of the increasing involvement of government in our society and the root of major public policy issues of the future, including many of those related to food and agriculture.

The theme of this address is normative and prescriptive. Stated simply, it is that the complexities and interdependencies of our society require of agricultural economists a more holistic, integral view of agriculture and public policies than is evident in our current agenda. We should broaden our professional perspectives, cultivate new clientele and professional alliances, recast and reorder our agenda, and experiment with modified and new institutional arrangements. In so doing we could better address emerging public policy issues and better serve the public interest concerning food and agriculture.

Beginning with an overview of the setting

Presidential address.

Kenneth R. Farrell is deputy administrator, Economic Research Service, U.S. Department of Agriculture.

The insightful, penetrating comments of James T. Bonnen and Harold F. Breimyer are acknowledged appreciatively. Other helpful comments on early versions of the paper were received from numerous readers in the U.S. Department of Agriculture, several land grant universities, and the Farm Foundation. The author is indebted to Geneva A. Riddle for her patience, dedication, and skill in typing numerous drafts.

for national public policy and some major national policy issues derived therefrom, I then review our past performance in policy analysis and conclude with a series of recommendations concerning reorientation of our agenda including supportive actions by the AAEA and the creation of a new public policy institute.

The Policy Setting

The most basic feature of the current policy setting is agriculture's growing social, economic, and political interdependence. Whatever insularity there once was in the sector is giving way inexorably to the pervasive integrating effects of extended markets and communities. The economics and politics of food and agriculture are no longer just those of the "farm bloc" or the agricultural establishment but also those of many diverse groups who lay joint, competitive claims upon resources used by agriculture or are impacted by economic performance of the food and agriculture complex. Our international interdependence includes but extends beyond immediate commerce to foreign economic development and food and technical assistance and comes wrapped in altruistic and moral as well as pecuniary and acquisitive terms.

In brief, U.S. agriculture and its role in world affairs has been transformed radically and irreversibly. The upshot of these circumstances, rooted deeply in the processes of economic development, changes in human aspirations and social goals, and new political realities, is to make it increasingly difficult—if not impossible—to analyze and understand agriculture and related public policies except as an integral part of national and world economic, social, and political systems.

An outgrowth of this increasing interdependence is heightened conflict between traditional agricultural and other interest groups in the affairs of food and agriculture. Examples abound: the clash between agricultural and environmental protection interests, between agricultural and urban interests in development and use of water and energy resources, the enactment of stringent standards related to food quality and safety, and export embargoes of agricultural commodities to control domestic food prices. Although we continue to rely principally upon market mechanisms to resolve such conflicts, at the same time we involve the government to alter outcomes or remedy deficiencies of the market. At the very heart of these issues are the economic questions: Who gains and who loses from government involvement in our economic system? What is the net benefit to society of that involvement? If there are positive net benefits, can losers be compensated such that benefits are not offset? What are appropriate measures of economic gains and losses and in what time frame?

These heightened conflicts are not transitory. They seem likely to broaden and intensify as policy trade-offs become more sharply defined in a context in which our capacity for economic growth at rates of recent decades, or even its desirability, is in question.

Schuh suggests that "the basic change in conditions of supply (of food) for the future involves a shift from factor supply conditions for primary inputs that are relatively elastic to a world of rising supply price for these inputs due to the need to bid them away from the nonfarm sector" (p. 5). Others find evidence of declining total factor productivity in farming and express concern about agriculture's future capacity to increase output without much higher real commodity and food prices than experienced in recent decades. With respect to energy sources and costs, we sit on a veritable "time-bomb" procrastinating in the development of realistic policies while growing steadily more dependent upon foreign energy sources. Yet almost any policy initiative involving the development of indigenous fossil fuel sources is likely to bring the interests of agriculture, rural communities, environmental interests, and energy-producing industries into sharp conflict.

The recent return to production of nearly 40 million acres of cropland held in reserve by government, the high cost of bringing additional land into production, the annual disappearance of 25,000 acres of cropland to sprawling urban development and other uses are bringing us gradually to the realization of the need for socially and economically rational long-term land use policies. Here, the interests of agriculture, rural and urban communities, environmentalists, and land developers seem certain to escalate in conflict.

With the trend of population growth having turned toward rural and small town areas since 1973 (Beale), the reliance of persons on 1.8 million farms for more than half their incomes from nonfarm employment, and a near equilibrium in the agricultural labor force (Schuh),

rural development has become a de facto part of overall national economic development.

Structural changes in the food and agriculture complex and the very uneven distribution of economic power within the complex pose other basic policy issues. Continued concentration in food marketing in farming and input supply industries gives rise to a series of fundamental policy issues involving tradeoffs between equity and efficiency. If, as recent projections suggest, 13% of all farms will control 70% of farm output by 1985, the very premise of traditional price and income guarantees and a wide array of other public programs predicated on the model of a purely competitive industry soon will be in question.

But the conflicts and necessities of public choice concerning food and agriculture can by no means be considered adequately within national economic, social, and political boundaries. We are inextricably involved in the fundamental problem of providing adequate diets for the burgeoning world population. Some agricultural economists believe that events in world food markets during the past four years were transitory, an aberration of the long-term condition of large supplies of commodities relative to effective market demand. They await return of surpluses and reincarnation of federal government supply management programs. Two generations of agricultural economists reared on the economics of surpluses, government-supply management programs, low commodity prices, and depressed farm incomes do not easily change their hypotheses and mind-sets.

Other economists believe that in the absence of serious economic dislocations, world demand for agricultural commodities will grow comparatively rapidly. They base their conclusions on the broad forces of population growth, rising affluence, consumer aspirations for, and political commitments to improved diets. The result would be relatively high levels of real farm product prices and incomes. Parenthetically, this outcome would present policy problems less familiar but no less perplexing to contemporary economists than the first one.

Even if "optimistic" projections were to be realized, they could hardly be termed favorable for many millions of persons in regions where food deficits seem likely to grow even as world food production increases. A recent analysis projects a total annual cereal deficit of about 100 million tons in developing market economies by 1985 compared with 45 million tons in 1974–75 and 28 million tons in the relatively good production period 1969–71 (Int. Food Policy Research Institute).

The starkness of such projections clearly poses fundamental economic and food policy issues for the developing market economy countries. For example, how do they acquire capital for agricultural development, and what policies are appropriate to induce increased food production while maintaining political stability and economic growth?

For the United States the issues are also numerous and important—issues that could well be exacerbated by instability in food production and political decisions in the centrally planned countries. Foremost in the immediate future may be the issue of the level and management of food reserves, nationally and internationally, to cope with short-term instability in production. But more generally, what type and mix of policies related to domestic agriculture, foreign trade, food aid, technical, and economic assistance should be pursued in the United States? What are the economic tradeoffs among related policy goals and instruments?

On the political side, any policy proposal centered on food and agriculture, even narrowly centered, must now run a broad gauntlet of special interests in the increasingly pluralistic, diffused national policy-making process. For example, in the 1975 hearings on a bill that would have adjusted target, loan, and purchase levels for major crops and the price support level for milk, testimony was submitted by representatives of ninety-two organizations ranging from the U.S. Labor Party to the American Beekeeping Association (Spitze).

Also to be reckoned with in the enactment of legislation is a multiplicity of institutions, new and old, in the legislative and executive branches and shifting balances of political power that condition the policy setting and the tone and scope of policy debate. Recent action in the executive branch consolidates food and agricultural policy review and formulation and restores an interdepartmental leadership role to the secretary of agriculture. Nevertheless, viewpoints and influence on policy issues continue to come from diverse quarters including the Departments of State, Treasury, and Commerce, the Office of Management and Budget, the Council of Economic Advisers, and a variety of other White House-created offices. Trade-offs among conflicting national

goals and perceived constituent and bureaucratic goals abound and manifest themselves in sometimes mysterious ways in the policy-making process. Clearly, agricultural policy is not being left to the agriculturists. In Paarlberg's terminology "the agricultural establishment has, in large measure, lost control of the farm policy agenda" (p. 96).

This overview of the policy setting implies that food and agricultural policy must be viewed in a much larger, more complex social, economic, and political matrix than was so even a few years ago. Even debate on new commodity price legislation in 1977 seems likely to go beyond the traditional agenda to include assessment of the relative merits of the proposed policy instruments within overall government spending ceilings: their impacts upon and distribution of benefits within and between commodity subsectors; the level and stability of food prices; the welfare of low-income consumers; their consistency with foreign trade, foreign aid, environmental quality, and nutrition goals.

Some observers of the policy scene suggest that not agricultural policy but food policy will be enacted henceforth. They use the term food policy to convey the need for a comprehensive, integrated set of national policies centered on food. Incorporated would be traditional agricultural price and income policy with elements of other national policies—foreign trade and aid, nutrition, environmental protection, and overall national economic policies, for example. Although it might be questioned where the boundaries of a comprehensive food policy could be logically and usefully drawn, we appear in some respects to be moving toward such a policy in an incremental, ad hoc, unplanned, even unconscious way. Elements of such a policy appear in the omnibus economic planning bill, the so-called Humphrey-Hawkins bill, and in the National Food Policy Act of 1976. Although neither bill seems likely to be enacted in the near future, they may well be precursors of the scope and setting of future policy debates involving food and agriculture.

Our Performance in Policy Analysis

Judgments of the performance of agricultural economists in policy analysis vary widely. In the spirit that constructive criticism can be salutary, the following observations are offered.

Output of the profession gives evidence of declining emphasis and effectiveness in dealing with policy issues faced by policy makers. In the formative years of the profession policy analysis was central to our activities. Much of the research of the period 1930–60 focused upon major commercial agricultural policy issues of that time and, in the early part of that era, dealt with creation of institutions to cope with those issues. Ideas and individuals moved freely between the colleges of agriculture, the U.S. Department of Agriculture (USDA), and policy-making forums. Brandow's agricultural policy review gives impressive evidence of the vitality and richness that once characterized commercial agricultural policy analysis.

But more recently the sense of excitement and involvement in those policy issues has wavered and waned. Ideas and individuals now seem to move less freely between Washington and other locations or even within Washington. To be sure, there is still some highly useful and timely policy analysis, a part of which never appears in professional outlets. But many of our analyses do not focus upon major policy issues of the type previously outlined. On very narrowly drawn issues, particularly those involving small incremental changes in commodity price programs, agricultural economists do quite well. But fewer and fewer policy issues can be bounded so narrowly. When we do address the big, complex, and controversial long-term issues—and that is not often—we do much less well. It is ironic, perhaps symptomatic, that this should be so at the very time our technical capacity to quantify economic relationships and handle large numbers of variables and masses of data has grown enormously.

Policy analysis is an integrative and adaptive process with respect to available knowledge and data, "a science of muddling through" (Lindblom). Thus, its quality is dependent upon the current stock of "research capital." Here, too, there has been deterioration. Too frequently we are forced to rely upon outdated estimates of important functional relationships and to find the results of past, more specialized research nonadditive in context of the policy issue at hand.

We are handicapped by inadequate knowledge of linkages between environmental quality and food production, of impacts of a host of institutional factors on foreign demand for U.S. commodities, and of linkages between macroeconomic variables such as employ-

ment, income, and domestic food demand. The currency and reliability of estimates of commodity supply, demand, and price relationships are in question. Coupled with obsolescent data systems (Bonnen 1975) and possible structural shifts in key economic relationships, even our preparedness for addressing conventional policy issues must be questioned.

Our analyses suffer from being excessively partial and insular. In an interdependent economic system in which horizontal, vertical, and feedback linkages abound, both conceptual and empirical models suggest commodity, functional, and sectoral independence. A great deficiency in recent years has been our failure to link foreign trade and domestic economic relationships to reflect their jointly determined nature. Linkage of the livestock and feed subsectors in the domestic economy needs strengthening. Despite large investments over the past thirty years under the Research and Marketing Act, we still have only very crude models linking the farm, input, and product markets. We have inadequate descriptors of the total food sector, its capacity, efficiency, and performance—only a set of fragmentary rough indicators predicated in part upon agriculture of the distant past. The subsector, systemwide, and worldwide models for policy purposes are generally inadequate (Fox, Johnson).

Policy-oriented research also is partial in the sense that many analyses stop short of tracing out full impacts of policy instruments. Too frequently analysis is limited to aggregate impacts on the farm sector, overlooking differential impacts among regions and upon the distribution of incomes within the sector and impacts upon consumers, government expenditures, and environmental quality. This condition limits our credibility and relevance for these are the interfaces at which crucial policy debate and trade-offs are occurring.

In part because of a fixation with neoclassical models of perfect competition, agricultural economists have embarrassingly little to offer on public policy issues centered on concentration of economic power in the food complex and in international trade. We seem more inclined to describe and document the past than to analyze the causes of changes and the full implications of current alternative market structures. We know much less than we should concerning the impacts of a plethora of government statutes and administrative procedures upon market structure, behavior, and performance, nationally and internationally. There is a paucity of research concerning international commodity agreements, marketing boards, and state trading devices. Despite their massive dimensions, little is known about the impacts of domestic food aid programs upon demand for food or the welfare of consumers.

Finally, we circumscribe ourselves too severely by our emphasis on production agriculture. At one time it was clear that public policies in the immediate economic interest of farmers were broadly consistent with the public interest in food and agriculture. The "farm problem," rooted in excess resources and chronically low personal incomes, was accepted as a national social and economic problem.

But today with improved personal incomes in agriculture, widening competition for resources between the farm and nonfarm sectors, and mounting public concern with externalities of farm production technology, that identity is much less clear and certain. To be sure, the maintenance of an efficient, productive agriculture is still in the public interest, however defined. But many other competing interests must be balanced against the economic interests of agriculture. Both because we purport to be social scientists and because of our public funding, we are obliged to include those interests on our research agenda and in policy analysis.

Further, I am convinced that the economics of agriculture cannot be analyzed and understood by looking only at agriculture. Our "charter" does not preclude us from beginning our inquiries well beyond the institutions of the farm sector or even the whole food and fiber complex. For example, I see nothing in our role as publicly funded agricultural economists that should preclude greater emphasis on household consumption economics as a means of better understanding consumer behavior in the interests of consumers. Similarly, with the economics of development and use of natural resources, rational public policies can be derived for a subpart only as we understand the whole. To paraphrase a social scientist from another discipline, it ought to be the primary professional commitment of social scientists, at least those whose work has some public resonance, to make their contribution to public life genuinely pluralist and thus make possible to all groups the enjoyment of equal benefits from their knowledge (Green).

From what sources do these alleged shortcomings in policy analysis derive? Certainly one of the external forces must be simply the complexity and interdependence of our social, economic, and political systems. How do we deal analytically with a process that has no beginning or end and whose boundaries are most uncertain, except to "muddle through?" Another force that led to decline in policy interest by economists is the lack of intellectual stimulation in the commercial policy issues of the 1960s. In a sense, commercial agricultural policy institutions matured between 1930 and 1960. Thereafter, until the early 1970s, we merely tinkered with and fine tuned those institutions—hardly a stimulating venture in an era of widespread alienation with public institutions of all type.

To derive a fuller explanation of our alleged shortcomings we also should look within the profession. I suggest four internal, interrelated determinants: our professional orientation, our methods of inquiry, institutional limitations, and inadequate delivery and feedback mechanisms. Some would add a fifth, the inherent limitation of received economic theory, particularly welfare theory, as an explanatory variable.

As for professional orientation, we may be party to what Lekachman dubs the "socialization" of economists—a process involving a system of education emphasizing belief, not reality. In any event we seem to have increasingly internalized the derivation of our research agenda and reinforced the process by the nature of our incentive systems and accreditation institutions.

Scholarship, it seems, is subject to singularity, to confinement in scope and method. One reason lies in our feeling more competent and therefore more secure in addressing narrowly defined problems.[1] By training and by desiring peer approval as scholars and scientists, we reinforce the singularity and confinement of our research. In the policy field we have tended to separate resource, development, trade, and marketing policies from agricultural policy and to embellish them with special pedagological and methodological mystiques. Much of the analyses of public policy issues that I have sketched, if it is to be done well, must be multidisciplinary, involving technical as well as economic relations and other social sciences (Hathaway). Yet we promote and perpetuate disciplinary and subdisciplinary independence by internalization of our research agenda and in the way we organize research and education institutions.

Internalization of our agenda is closely linked to our methods of inquiry. The view of economics as a science and the associated growth in application of statistics, mathematics, and econometrics to agricultural economic phenomena have elevated positive economics and quantitative methods to dominant positions in graduate school curricula and research. As the numbers of trained students increased, became professors and leaders in the profession, and in turn created more practitioners in their image, the design of a reward system giving emphasis to quantitative analysis completed the cycle. Unlike Adam Smith, contemporary economists pride themselves on their "value-free" analyses. If we aspire to deal realistically with the major policy issues of our time, we must inquire about societal goals and priorities, for it is from evolutionary, sometimes radical, change of those goals and priorities that major public policy issues arise.

Leontief's accolades of agricultural economics as a branch of economics in which scientific methods are applied to observable facts still ring fondly in our ears. Some of our research does blend quantitative methods with knowledge of institutions and observable facts to yield useful and believable results. But the question arises as to the extent to which means of analysis have become ends of analysis, whether demonstration of capacity to develop sophisticated quantitative models and publish in professional journals has become a goal in itself irrespective of whether the model or the data employed conform to reality or whether the results are useful to anyone. Getting the model "to run," as if it then assumed a life and purpose of its own, is an occasion of great accomplishment for some. But the test of accomplishment should be the reliability of its predictive powers and ultimately whether it assists in understanding any important economic relationship or in making any consequential economic decision, public or private. Perhaps it was similar concern that led one critic to decry "the spectacle of so many people refining the analysis of economic states which they give no reason to suppose will ever, or have ever, come about" (p. 2) and another to observe that economics

[1] The author is indebted to Harold Breimyer for statement of this idea.

has "a marvelous array of pretend tools which would perform wonders if ever a set of facts should turn up in the right form" (Heller, p. 2).

Such criticisms can easily be overdrawn. It seems to me that our excesses are not in the first place having sought to develop, refine, and apply such tools. Surely the justification for our discipline rests upon more than theory, intuition, and judgments based on personal experiences. If we are to be criticized it is in having become excessively reliant upon quantitative methods while failing to emphasize the inherent limitations of required assumptions and dependent data systems, to invest in development of those systems, and adapt imaginatively our methods to consequential economic questions. As for debate on the relative merits of institutional and positive economics in policy analysis, I find little that is productive. It seems obvious that a blend of the two is required by the very purpose of policy analysis and by the reality of public policy issues. But until we make a fuller commitment to apply economics to important public policy issues and strike a better balance in our agenda between the pluralist public interest and our internal professional interests, it matters little whether we are positivists, institutionalists, or some mixture of the two. To paraphrase Gordon, we should examine the trade-off between rigor and relevance of our research.

Much has been said recently on the limitations of the agricultural research establishments (National Academy of Science 1972, 1975; Hightower). Criticism centers on alleged lack of openness and responsiveness to needs of various nonagricultural interest groups—again the issue of special interest versus public interest and in turn the scope and focus of our research programs. We might question the extent to which we have become captives of old line institutions and thereby limited our capability to adjust to changing circumstances and policy issues, particularly those involving interests of nonagricultural groups. Bonnen points out "the institutions of agriculture have grown up as a closed, isolated system, and they are not well related to the new power centers of modern industrial society" (1974). Schultz worries about the possibility that we are becoming subservient to government, the result being that most agricultural economists find government actions in agriculture too controversial and too unsettled for analysis.

There are other features of our institutions that limit our ability to deploy resources sufficient to attain the scale, intensity, and direction of research effort needed to address complex policy issues. They include spatial diffusion of research organizations, ineffective coordinating mechanisms, the fractionated, episodic nature of research in most universities, and the short-run crisis orientation of much of the research in government. To that one might add the ingrained independence of researchers!

To some extent our inadequate performance is attributable to our poor communication skills and inadequate information delivery and feedback mechanisms in the pluralistic policy-making process. We need to invest more time and effort in two-way communication with policy makers and the general public. Some useful economic research never reaches relevant decision makers; some only reaches them in the obscurity of technical reports. This requires development of communication skills and more attention paid to "packaging" information for the particular needs of users. In this vein, the recent policy publications of extension are to be commended.

Conclusions and Recommendations

At this point you might ask, "What's right in agricultural economics?" To be sure, we have a professional heritage marked by pragmatic, useful application of economic theory and quantitative methods to the practical problems of American agriculture. We have a rich diversity of human capital in terms of technical training, accumulated knowledge, and professional experience and interests. The diffused and pluralistic structure of our research and extension programs provides a basis for "staying in touch with reality." They encourage individuality and diversity in viewpoints and methods. But institutions, if they are to survive, must adapt to changes in their environment and in the expectations of those who legitimize their roles and being in society.

Reorientation of our agenda and development of more effective research and education institutions are long-term processes requiring adjustments of several types. Some are as basic as altering curricula in graduate schools to provide greater diversity in training and exposure to institutional economics, welfare economics, and policy-allied disciplines such as political science and philosophy. Just as

basic is the need to instill a greater sense of commitment to analysis of public policy issues on the part of those already practicing. We could begin by raising our consciousness of policy issues, asking who is the intended recipient of our research, and asking what information is needed in the hierarchy of decision making within which public policy is formulated and implemented. In doing this we need to look through a much broader prism that includes the interests of many groups in addition to those directly associated with production and distribution of food and fiber. Basic to all of this is the redesign of the reward system in our institutions to encourage and support policy analysis and public service. It also is essential that administrators develop courage and willingness to protect those who choose to deal responsibly with conflicts inherent in major public policy issues.

Some resources could be gained for policy analysis by redirection from current activities of low social value. A part of our efforts is still of a service nature to firms and groups of firms, some of which could and should be provided by the firms themselves or acquired through private research organizations. Some research is so microcosmic and adds so little to knowledge that it would scarcely be missed. We could cease to collect, massage, and publish data that no longer conform to reality or are of use to only a few with vested self-interests. We could critically appraise the premises of some of our work lest in Bishop's terms we find ourselves further down the road to becoming publicly-subsidized consultants than we realize.

However distasteful, we also must find more effective mechanisms for joint planning and conduct of research and extension programs. Whether it be by modification of regional project approaches, by more extensive use of "competitive bidding" as opposed to formula grants of public funds, or by exertion of more positive, imaginative leadership and use of discretionary funds on the part of the larger, more strategically placed institutions, we must surely secure a higher degree of coordination and purpose than now prevails in our diffused research and extension establishments. The alternative may be a centralized, autocratic system imposed upon us, the embryo of which is present in proposals concerning federal funding of agricultural research.

Some rather simple initiatives could be taken within the research and extension establishments to stimulate interest in and improve the quality of policy analysis. The "apartheid" conditions separating research and extension in some universities should be eliminated, and researchers should understand that they have a responsibility for "packaging" and delivering their products to policy makers. It is simply too easy to report research in arcane, technical jargon, leaving others to translate for the wider audience. The reciprocal is that extension economists should become more deeply involved in the research process.

My own institution, the Economic Research Service (ERS), has not been as effective as it might be in bridging between universities and policy makers. More could be done by the ERS to improve the flow of information on policy issues arising at the national level; to assist university personnel in channeling their research to appropriate policy-making forums; to provide "clearinghouse" services for the profession by providing information on policy-oriented research in progress. Both universities and the ERS could benefit from a wider flow of ideas and personnel between the two. Some beginning efforts have been made to improve those linkage mechanisms.

We also could benefit from more formal research linkages with our counterparts in foreign countries. In this respect linkages with the developing countries seem more advanced than with the developed countries, although in both cases arrangements are episodic and rarely in the nature of the truly collaborative research on issues of mutual interest. We also need to vastly improve our data and knowledge bases concerning foreign agriculture, trade, and policy institutions.

Finally, there are initiatives that could be taken appropriately by the AAEA as the one institution that spans, or is capable of spanning, the whole profession. The dialogue we have twice yearly in large meetings is important but not sufficient to give impetus to expanded, more effective public policy analysis. I suggest for your consideration the following actions.

(*a*) Establish an annual award to recognize outstanding contributions in the profession to the advancement of public understanding of major policy issues with preference to contributions that are multiunit or multidisciplinary in nature.

(*b*) Invite or commission a series of papers

setting forth major public policy issues concerning food and agriculture and the implications of policy options related thereto. The forthcoming policy debates turning on expiration of the Act of 1973 provide an opportune setting for the latter set of papers.

(*c*) Over the next several years sponsor a series of seminars, workshops, and public forums to stimulate interest and understanding of contemporary policy issues within and outside the profession. Some of these ventures might be oriented toward methodology or curricula, some designed for problem identification, and others for planning purposes.

Although each of these adjustments and initiatives would be helpful, I believe we should go further. We should undertake serious discussion of the feasibility of creating a national food and agricultural policy institute endowed by public and/or philanthropic foundation funds. Its focus should be primarily national although obviously in an international context. It should concentrate on long-term, "basic" research, particularly that which is multidisciplinary by nature. A core staff could be augmented by visiting scholars, domestic and foreign, for terms of at least two years. Such an institute need not duplicate research in other endowed organizations, most of which have no singular focus on food and agriculture. Nor need it be highly competitive with publicly funded agricultural economic research institutions. It could very well complement those institutions while mitigating some of the deficiencies in current research approaches and institutions—the fractionated, episodic, and short-run nature of research and proximity of our institutions to traditional centers of power. The AAEA is the most appropriate forum for initiation of discussion of the merits of this suggestion.

In conclusion, we face as social scientists a great challenge and opportunity to serve a very broad and fundamental public interest in food and agriculture. We can best serve that interest by broadening our perspectives, cultivating new clientele and professional alliances, and recasting and reorienting our agenda and experimenting with modified and new institutional arrangements in the profession. In emphasizing public policy analysis and the application of economics in the interest of the many groups concerned with food and agriculture, we will be in the best tradition of the egalitarian principles of Jefferson and the humanistic principles of Adam Smith's political economy.

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Agricultural Economists and Public Policy

Lauren Soth

In annual conclaves of scholarly associations, it is standing operating procedure for the members to ask themselves about their role in the workaday society. Being devoted to teaching the young and searching for new knowledge, living in semicloistered retreats, professors and researchers require mutual reassurance that they are doing things that are worthwhile in the real world.

Self-examination is healthy. I feel that I am following an honored tradition in this association by undertaking a discussion of the topic. But at the outset I must say that agricultural economists have less trouble with the deprecating question—what good are we?—than most people in the academic disciplines. They have had another hangup, as I shall explain.

Agricultural economics in the United States has been almost wholly a pursuit of the land grant agricultural colleges and the U.S. Department of Agriculture. It grew naturally out of the soil and climate of this public educational federation, where practicality was the watchword. Agricultural economics came out of dirt farming, as they say on the political campaign circuit, crops and soils technology, animal husbandry, farm management, and later marketing of farm products. Many of the early agricultural economists started their careers as teachers of animal husbandry or farm management. They did not first study economics and then turn to specialize in the economics of agriculture. By and large, it was the other way around.

The nature of the origins of the agricultural economics profession led to a feeling of inferiority among its early practitioners. I often sensed, when I was taking graduate work in economics and doing extension jobs in farm outlook and public policy questions, that agricultural economists at Iowa State and in the USDA were touchy about their lack of grounding in formal economics. Some of them flaunted their practical knowledge of farming or of agricultural markets and made light of the theories in textbooks. Others tried to prove themselves legitimate and worthy members of the profession of Adam Smith, David Ricardo, and Alfred Marshall.

The circumstances under which agricultural economics began to develop as a separate field of study gave the profession an advantage in the practical world of politics and business. Unlike the workers in most social sciences, including general business economics, the agricultural economists really knew their industry. Moreover, their innocence of theoretical economics enabled them to appreciate the power relationships of the market and to see the wide gap between the textbook principles and the way the economy actually functioned.

I

Agricultural economists have had more influence on the formulation and the carrying out of public policies for their industry, I should venture, than the economists specializing in any other single industry. In the 1920s, when agriculture was suffering from the plunge of prices after World War I, agricultural economists provided the intellectual leadership in designing plans for government action and for structural reforms of the marketing system. W. J. Spillman, Henry C. Taylor, M. L. Wilson, Henry A. Wallace, E. G. Nourse, and John D. Black are names that spring quickly to mind. These were the idea men behind the export debenture plan, the domestic allotment plan, the McNary-Haugen bill, the farm cooperative movement and other proposals for helping farmers contend with overproduction and low prices.

The prevailing diagnosis of the cause of the farm problem at this time was loss of foreign markets. Farmers had expanded production to sell abroad in the golden years of the early 1900s, so the reasoning went, and then increased output still more to meet the needs of

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Fellow's lecture.

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World War I. The setbacks to foreign sales in the 1920s resulted in commodity surpluses. Farm relief plans generally focused on aspects of the foreign trade situation. Agricultural economists called for lower tariffs on manufactured goods to stimulate imports and furnish dollars to foreign customers for our farm products. They urged export subsidies for farm products, two-price plans such as the McNary-Haugen bill and the export-debenture scheme.

These early agricultural economists were unabashed political economists and partisans for farmers. They pushed the American development theme as espoused by the founding fathers and reflected in the Morrill Act, the Homestead Act, and throughout our public policy. In his *Agricultural Reform in the United States,* published in 1929, John D. Black defined the objectives of national agricultural policy as "first, to hasten the improvement in the rural scale of living; second, to check the present rapid rate of migration to cities; and third, to maintain a somewhat larger proportion of our population on the land than otherwise would be the case" (p. 60).

Black was the principal designer of what was then called the domestic allotment plan, a plan for retiring temporarily part of the land used for major crops. The aim was to reduce output and raise prices of farm products. When prices sagged drastically in 1930, 1931, and 1932, this plan became widely accepted among farm groups. In his one speech on agricultural policy in the 1932 presidential campaign, Franklin D. Roosevelt gave a fuzzy endorsement to the idea. After the election the New Deal Congress approved the first Agricultural Adjustment Act. That has been the fundamental system of supply management ever since, and though it is in abeyance at the moment and the political language has evolved to "set aside" instead of annual allotments, the essentials of the system are the same as forty-three years ago.

Black was advocating methods of supporting farm income that he thought would keep people on the farm and that he considered a desirable national objective. Two of his three objectives for farm policy had to do with maintaining a larger farm population than would prevail without a federal action program.

As it turned out, the domestic allotment plan had the opposite effect. It helped farmers who were in a strong financial position to acquire more land; price supports enabled the big farmer to gain substantially in competition with the small operator. Ironically, the allotment and price programs were criticized at first, by many agricultural economists as well as conservative politicians and business men for protecting the outdated, inefficient, small farmer and blocking modernization of the industry. Some naive urban critics of "farm subsidies," such as the *Wall Street Journal,* have continued even in recent times to charge that the farm programs inhibit efficient, large-scale farming.

It is true that, on its face, the legislation promises certain advantages to small farms, and all farm laws religiously proclaim their purpose of upholding the family farm. But the real effects were quite different, as became obvious to those who looked at the facts after World War II instead of basing their opinions on legislative preambles and theory.

II

There then arose a heresy within the professional agricultural fraternity of the land grant system, including some farm economists. The heretics repudiated the ancient Jeffersonian doctrine about the virtues of the family farm.

Even into the 1930s, farm policy reformers sought to preserve independent, small-scale farming and rural communities. They did not seek a change in structure of agriculture but mechanisms to improve its functioning. The philosophy of the Morrill Act, the Homestead Act, and the Country Life Commission of Theodore Roosevelt dominated the land grant colleges. The purpose of research and education was to raise the farm family to an urban living standard—not drive people off the farm but keep them there. Extolling the virtues of rural life was part of the ritual of extension work.

But the new technology was seen to be depopulating the farms as it reduced labor requirements. Making a virtue out of necessity, agriculturalists began to laud modernization and consolidation of farms and the "release" of farm workers for nonfarm work.

The family farm ideologists came in for condescending smiles if not contempt. It was time to recognize farming as a business and not a way of life. Agricultural economists began to talk about farm population adjust-

ment as a "final" solution of the farm surplus problem. It was not a problem of overproduction but of too many people sharing the national farm income. Instead of trying to restrain farm output so as to increase farm income, what was needed was continued reduction of farm population to increase the individual shares.

At the same time, after World War II, as Brandow has lucidly explained in his review of the literature on commercial agricultural policy, agricultural economists turned to the demand side as an explanation of the farm problem. The lesson of World War II had been that when the economy was in boom, with full employment, prices of farm products were high and farmers were prosperous. Most importantly, young people leaving farming areas could get jobs in the cities. The farm problem was not really a farm problem but a problem of general economic stabilization on a rising trend of growth.

This analysis was happily in harmony with the "permanent adjustment" theme. It also furnished timely justification of the conventional land grant doctrine that full-speed-ahead infusion of new technology was all to the benefit of farmers and the rest of us. The same rationale was comforting to those who wanted to "get the government out of agriculture" and let free markets reign.

The technological faith had come into question by a few farm radicals and a few dissident farm economists who made the logical connection between excess supply and new methods that increased production. So, it was nice for the true believers in science to hear other respected economists rebut this by arguing that the farm problem was caused by weak demand for farm products. The free marketeers were not disturbed by government financing and investment in new farm technology as an intervention in private business—only "artificial" meddling in what they regarded as natural markets.

Unfortunately for the final solution proponents, it soon became apparent that full employment and continued rapid reduction of the farm population were not enough to keep farm income high. The overproduction tendency seemed not just a matter of weak foreign and domestic demand; it seemed to be chronic, if irregular. Even with high employment, prices of farm products and the net incomes of farmers often were below satisfactory levels.

III

Agricultural economists attributed the farm problem first to loss of foreign markets, then to slack domestic demand. They were slow to appreciate the consequences of the technological revolution in farming. The application of science to agriculture was regarded as a "given" in the farm economics equation—beyond economic study. The land grant college-USDA system, in all its parts and roles, was based on the idea that technological efficiency is an ultimate good. There could not be too much or too fast a drive for getting more output per man, per acre, or per unit of capital.

Alone among the agricultural establishment scholars, a few economists braved the theologians of technology to ask whether the push for technical advance might be too impetuous. They asked whether the overcapacity of agriculture could be the result of letting technology get ahead of social adjustment. They suggested that priority in public expenditure for rural communities ought itself be subjected to scientific analysis.

Considering that these questioners of the dogma were themselves employees of the land grant system, they deserve praise for courage. Nearly all criticism of public agricultural research policies has come from within, not from agricultural economists in private educational, research, and business institutions, where you might expect it to originate. Instead, the outsiders mostly have beaten the drums for all out production research, that is, the development and application of new technology for agriculture, including the major farm organizations.

Agricultural economists inside the system were first to point out that farmers taken as a group did not benefit from the introduction of new methods; only the first users did. They dared to challenge the time-honored experiment station sales argument to legislatures that an increase in corn yields increased farmers' aggregate income. Public spending for agricultural improvements benefited the American consumer and the foreign buyer, not the farmer. Agricultural economists showed that the bypassed farm operators, hired workers, and small towns in rural areas benefited least of all or not at all from new farming technology. The discernible effects of these studies on public policy are small so far,

but I am confident that they will ultimately be substantial.

Agricultural economists have brought to bear on the intellectual front the nonfarm or nonagrarian concerns that are becoming apparent on the political front. The farmer in the last 200 years has felt that interests outside farming—the middlemen, bankers, railroads, and manufacturers—were making the main decisions about his business. He has had to take the other fellow's price, both as buyer and as seller.

Actually, in this century government farm policies have been largely left to the farmer and his organizations, including the land grant institutions; farm lobbyists have been able to get most of what they wanted. The decline of farmers in number and proportion of the voting population did not weaken their power in government, despite reapportionment. Yet the farmer's instinct about being at the mercy of outside interests is not far off the mark. Government policies have been beneficial to the elite of commercial agriculture and to the business interests selling to and buying from them but often not to the majority of people in farming.

The political atmosphere on food and agriculture has changed in the 1970s. The rise in food costs to consumers, the deterioration of rural community structure, the trend to industrial agriculture, and the migration of displaced rural people to cities have attracted a wider constituency for farm policy.

IV

Agricultural economists as partisans and political activists contributed heavily to the nation's farm policies of the first half of the twentieth century.[1] As "pure" economists, more segregated from the political scene today, their influence has diminished. Agricultural economics undoubtedly has become more scientific, more scholarly, and more knowledgeable about the farming business. The more you know, the more detached from politics, the less likely you are to attract attention and stir opinion. The more specialized you become, the less effective you are in the political economy. As our studies have become more intensive, more detailed, with greater use of mathematical techniques, inevitably they become narrower. The impact on public affairs is remote, long delayed, and indirect.

I do not say this is a bad thing; I do not belittle the mathematical tools merely because I do not understand them. I must admit, however, that the remark of Joan Robinson, who refuses to use equations, gave me some satisfaction. She said, "I don't know math, so I am obliged to think" (Golden, p. 42). If I were to criticize the budget of research in agricultural economics, I should be more inclined to adopt another criticism of American economists made by Joan Robinson. She said they are floundering because they still have an ideological bias toward the free market, which she says is a theoretical concept that does not exist.

Scientific, mathematical studies about the economic details of agriculture no doubt help us understand the industry. But to the extent that they rest on assumptions about pure economic science, they are illusionary and not helpful in the formation of public policy.

I read recently an interesting paper by Paul McCracken, professor at the University of Michigan and longtime member of the president's Council of Economic Advisers. McCracken believes an economic adviser ought to try to keep his own values and political judgments separate from his advice on economics. I guess everyone would agree with that. But it implies that there is such a thing as economic science that can be divorced from politics. That I doubt.

McCracken tells about an incident when he and other advisers were asked to report in 1961 about the domestic economy and the balance of payments. One of their recommendations was that the gold reserve requirement be reduced or removed while the issue was quiescent, rather than waiting until the Federal Reserve's gold holdings were on the verge of becoming deficient. Kennedy said he understood the economic logic and the economic cost of delaying a decision, but he would have to pass. He said such legislation would have to come before Senator Harry Byrd, and he did not want to start his administration by raising the gold issue with the senator.

McCracken said he and the other advisers performed correctly as advisers, but the president, looking at the larger domain for which he was responsible, chose not to take their advice. McCracken said he understood that pure

[1] Among the many good books recounting the impact of farmers' political movements on government policy that tell of the contributions of early agricultural economists are those by Salutos and Hicks, Benedict, and Hofstadter.

economics had been adulterated in Kennedy's decision, and he had no reason to think the president was wrong.

I agree on this kind of separation of economics and party politics. But in the larger meaning of political economy, McCracken and his associates took into account more than pure economics in their assessment of the gold reserve question. They had to consider the power factors in banking and government among others.

In dealing with agricultural policy, as with money or other economic policy, it is impossible to consider economics as a pure science. Economics itself is more complicated than any physical science. It deals with pesky human behavior. It embraces power of large organizations more and more. We deceive ourselves and our clientele when we claim to be only "humble technicians" bringing to bear an antiseptic economic analysis on a public policy question.[2]

On the whole, agricultural economists have been broad enough to see beyond economics in public policy and to see that economics is more than demand and supply curves.[3] I could provide a long list of current AAEA members who have made large contributions to the agricultural policies of this country. But I'm a coward. I'm afraid I'd leave out a deserving stalwart or two and offend them, while offending others by including certain names. So I won't give you my list. Anyway, you all know the people who have served as economic policy advisers in the executive departments, directors of policy studies for Congress, members and directors of presidential commissions, and the authors of influential books and articles. It should be easy, at least in this instance, to support without documentation my claim that agricultural economists have been more influential in economic policies for their industry than other specialized economists have been for theirs.

V

In his 1967 presidential address to the AAEA, Bishop, who was then director of the National Advisory Commission on Rural Poverty, said, "those of us who work in the rural social sciences have not perceived the significance of the growing urbanization of rural America" (p. 999). He said farm economists had been preoccupied with the problems of the farm firm and had given little or no attention to economic problems much more important to the majority of the rural population.

Bishop asked that economists study the effects of farm programs on income distribution in agriculture and the effects of technology on the structure of rural communities. He said, "In order to increase our usefulness in coping with problems of economic structure and public policy, we must break the bonds of pure competition and extend our analysis to problems that transcend market phenomena" (p. 1007).

Nine years later I think one can say that the agricultural economists have been shifting in the direction Bishop advised. With consumer organizations becoming more vocal, with environmental concerns becoming imperative, and foreign policy once again rising to the forefront of agricultural policy, the trend toward a broader approach to public policy will continue. The public has awakened to the connections between farm policy and foreign policy, food prices, protecting the environment, and the rural-urban structure of society. The public says, in effect, that farm policy is too important to be left to the farmers, since that means in practice the big farmers and agribusiness.

The public is no longer willing to accept without question the assertions of the agricultural establishment that the United States has the purest and most nutritious food supply in the world. Nor is it ready to leave soil and water management to the establishment. Even the issues in rural areas of crime prevention, public welfare, education, the rights of minorities, and collective bargaining of farm workers will not be left to rural areas. As Bishop said, the rural society is becoming urbanized; its

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[2] Randall discussed "Information, Power and Academic Responsibility" perceptively in this *Journal:* "Conceiving the economy as a system of mutual coercion, it becomes impossible to avoid the moral dilemmas which confront anybody involved in the public sector or in social decision making. If an action taken in any public agency tends to increase the power of some people while reducing the power of others (i.e., to make some people better off and others worse off), its distributional consequences cannot be attributed to some inevitable and inexorable economic law. Rather, these consequences are the result of a decision of which that agency should be conscious and for which it must take responsibility" (p. 229).

[3] Randall asked, "What, then, is the normative significance of a supply curve, a demand curve, a price? Very little, I suggest, since all of these things are very largely dependent on the structure of power within an economy, and the structure of power can be changed by political action as well as by what we have come to think of as economic changes. Economic data such as prices and supply and demand curves can be used in a normative context only if the current structure of power is assumed optimal" (p. 229, note 9).

isolation is ending. The farmer and his community have been brought into the mainstream of the nation.

Paarlberg said, "The biggest issue of agricultural policy is . . . who is going to control the agenda. . . . The old agenda is concerned primarily with commodities and specifically with influencing supplies and prices in the farmer's interest. . . . The new agenda differs radically . . . : Food prices and specifically how to hold them down . . . ecological questions . . . rural development, primarily a program of the 80 percent of the rural people who are nonfarmers . . . civil rights . . . collective bargaining." Paarlberg also said the agricultural establishment should not just "repeat the honored rhetoric" but should recognize that the new constituency would have to be served.

I agree with him. Moreover, I think the nonfarm pressures on agricultural policy will be beneficial to independent family farming and to a healthier rural society.

Agriculture's own institutions, developed for an earlier time and for a different farming structure, are incapable of meeting the requirements for public policy on rural affairs today. The very success of the scientific advances in farming tended to freeze the institutions in place. The fact that the benefits of scientific advance were not being shared equally within agriculture and between agriculture and the urban sector tended to be ignored by the land grant system, the commercial farm organizations, and agribusiness.

There seems to be a law of nature that successful human organizations resist change until they have lost effectiveness and are replaced. Bonnen, our honored president, has frequently alerted us to what he has called "The Decline of the Agricultural Establishment." Ten years ago Bonnen said in a speech that "the commercial agricultural power structure has reached a state of extreme organizational fragmentation . . . and these fragmented elements are themselves contributing greatly to a general erosion of the political power which together they exert."

The politics of farming in the 1920s and 1930s had to do with a fairly homogeneous farming community. That community has been splitting apart from the effect of the technological revolution. Farmers' organizations have been splitting into agribusiness firms and into commodity groups. The colleges of agriculture and the USDA have tended to become more associated with larg farming interests and the suppliers of farm ir puts and the buyers of farm products. Th close association of the USDA with the pe ticide industry and the international grai companies has been notorious. Regulation ‹ pesticides has been taken away from USD/ and the regulation of grain inspection is bein reformed.

Agricultural economists have been the lea ers in calling to public attention the neglect ‹ low-income farm families and hired far labor, the effects of government farm pro rams on the farming structure, and the impa of technology on rural America. But the cha lenge laid down by Bishop is still pertinent one judges the profession by what appears i the *Journal of Agricultural Economics*. Publi policy issues till receive secondary effor especially those policies which affect the ge eral public.

For half a century the principal public po icy question concerning food and agricultur was how to deal with production overcapa ity; in the next half century the central pro lem could well be scarcity. High food cost and instability of prices will be public polic targets. Agricultural economists will fin themselves in a different position with respec to farm policy formation than in the past. W need more work on food and nutritio policies, foreign policy, national energy, an environment policies and the structure of a riculture and rural communities.

Perhaps I could be accused of bias, but I a confident that the members of the AAEA wi rise to the needs of the occasion as they hav in the past.

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The New Macroeconomics of Agriculture

G. Edward Schuh

Most of the literature on the macroeconomics of U.S. agriculture is cast in the context of a closed economy. Moreover, it considers a world in which there is rapid technological change and focuses on the problems involved in the so-called agricultural transformation—the process whereby an important share of the agricultural labor force is transferred out of agriculture and new modern inputs produced in the nonfarm sector are introduced. (For a survey of the literature on the agricultural transformation, see Johnston.) Consequently, it tends to ignore linkages to an international economy and focuses instead on the secular income problems that agriculture faces as it is subjected to the processes of economic growth.

This perspective no longer seems relevant to the major problems now facing U.S. agriculture. Outmigration from agriculture has declined markedly, long-sustained growth in factor productivity appears to be leveling out, and major shocks to the U.S. food and agriculture sector have come from abroad as a result of the American economy having become more open. At the same time, the rules governing the trade and exchange relations among countries have changed, and there is pressure for even further change as the less developed countries push their demands for a new international economic order.

This paper addresses these new conditions and the implications they have for us, both as a nation and as a profession. What perhaps most differentiates this paper from previous treatments of the macroeconomics of agriculture is an attempt to examine the agricultural sector in the context of an open world economy. Looking ahead, the major analytical and policy problems agricultural economists face will have to do with how U.S. agriculture and the economy as a whole fit into a rapidly changing, interdependent world economy. Those problems have to be understood in the context of our present stage of development and the major forces impinging on agriculture. Hence, part of my paper will be concerned with these issues as well.

The Setting

The contribution that agriculture makes to the economic growth of the larger economy is undergoing marked changes. In the past, its contribution consisted primarily of furnishing abundant supplies of food to the domestic economy at constant or declining real prices, the release of large numbers of workers to man an ever expanding nonfarm sector, and the supplying of large amounts of capital—both human and nonhuman—for the development of the rest of the economy. From the present perspective, the capital flow may now well be the other way; the outflow of labor has slowed in the aggregate, and food prices have recently risen relative to the price of other goods and services. Moreover, agriculture is a major source of export earnings and thereby provides the means to purchase the growing amounts of petroleum, raw materials, and finished products imported from abroad.

Agriculture continues to be an important market for goods from the nonfarm sector and in the recent recession was an important point of strength as farm incomes were sustained while the rest of the economy was in serious trouble. This was probably the first time in our modern history that a severe recession in the general economy had little effect on agriculture and was due in no small part to a strong export demand as well as the continual broadening of our welfare programs.

The early 1970s have seen major shocks to U.S. agriculture and economy. After a long secular decline in the real price of agricultural products, food and agricultural prices were in

Invited address.

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the vanguard of an unusual peacetime inflationary spiral. Rather than subsidizing exports, as was done in the past, some form of export controls was imposed in each of the last three years. Food aid on concessional terms was reduced dramatically as commercial sales abroad burgeoned. Average per capita incomes of farm people rose above those in the nonfarm sector. From a chronic problem of low relative incomes for farm people, a shift has occurred to what many believe will be a chronic problem of instability.

The question that emerges is whether these recent events reflect changes in the macroeconomics of agriculture. In my view they do. Some of the changes have important implications for the welfare of U.S. citizens and for policy makers as they attempt to devise policies that are in the best interests of the nation.

Changes in the Economic Environment of U.S. Agriculture

The U.S. economy experienced unprecedented growth in the decade of the 1960s. There was also unusual growth in other parts of the world, including some of the LDC's. The regime of fixed exchange rates established at Bretton-Woods broke down, and the world has fitfully moved to a system of floating exchange rates. Population growth around the world continues to press hard against the stock of land, despite technological breakthroughs in birth control, concentrated efforts by at least some countries to reduce their growth rates, and technological breakthroughs in agriculture that were prematurely labeled a green revolution.

I turn now to a brief look at the more specific changes relevant to agriculture.

Reduced Outmigration from Agriculture

It is generally recognized that the chronic farm problem of the 1950s and 1960s was a result of the inability to transfer labor out of agriculture at a sufficiently rapid rate. The United States had persistently underinvested in the education of its rural people, with the result that farm people often did not have the skills and talents required for nonfarm employment. The agricultural labor market naturally tends to be rather imperfect, in part due to its geographic dispersion. During the 1950s and early 1960s, fiscal and monetary policy caused the level of unemployment in the general economy to be relatively high, constituting an important barrier to the outmigration of labor.[1]

As we entered the decade of the 1970s, the agricultural labor market was approaching an equilibrium. Employment in agriculture has remained about stable since 1970, the real agricultural wage rate rose relative to the wage rate in the private nonagricultural sector from 1965 through 1974, and average per capita incomes in the agricultural sector were larger than those in the nonfarm sector in both 1973 and 1974.[2] Median family incomes of farm people, while still less than those of nonfarm families, have risen dramatically relative to those in the nonfarm sector.[3]

There will undoubtedly be a continued outflow of human resources from agriculture, particularly from the Northeast and Southeast. On the other hand, there may well be some return flows in other regions, and the aggregate outflow will most likely be greatly reduced compared to the past. Average annual net outmigration during the 1950s and 1960s was 741,000 and 592,000, respectively. From 1970 through 1974, the average net outmigration was only slightly over 110,000 per year, in a total labor force of some 90 million (Council of Economic Advisers 1975).

Stagnating Productivity Growth

Increases in total factor productivity have been an important source of output expansion in the past. From 1940 to 1970 total measured physical inputs in agriculture increased only 4%, while output increased 58%. Clearly, the major source of output expansion was an increase in factor productivity.

More recently, there has been a marked and little understood decline in the rate of measured productivity growth in agriculture. During the decade of the 1950s, total factor productivity grew by 27%. In the decade of the

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[1] Evidence on the role of unemployment in reducing the outflow of labor from agriculture can be found in Hathaway, Schuh (1968), and Sjaastad. For an explanation of why tight monetary and fiscal policies were pursued in the 1950s and early 1960s, see Schuh (1974).

[2] Supporting data for these assertions are readily available from public sources such as the *Economic Report of the President*. They will be provided by the author on request.

[3] From 1970 to 1973 median family income of the farm population increased by 30% in real terms, compared to 6% in the nonfarm sector (Council of Economic Advisers).

1960s it grew by only 11%, or at a rate only slightly more than a third as large as in the previous decade. This stagnation in productivity growth first emerged in the period following 1965 after a continued and sustained rise in the previous fifteen years. Total factor productivity grew by some 10% in 1971 but has again stagnated since then.

The National Academy of Science in May 1971 organized a Committee on Agricultural Production Efficiency to evaluate the adequacy of this nation's policies, knowledge, and technology relative to agricultural research and educational efforts. Although far from being a prognostication of doom, the committee's report is indeed sobering. Their data show rather strong diminishing returns from the application of fertilizer to land, with the rate of increase in crop yields per pound of fertilizer added tapering off since 1965. The number of eggs laid per hen is apparently leveling off at near 230 per year, and a similar biological limit is expected to emerge with respect to the production of broilers per pound of feed. In addition, the number of people fed per farmer and the number of people fed per acre are also leveling off.

In looking ahead, the committee indicated that no major scientific breakthrough comparable to hybrid corn or DDT can be reasonably predicted for the next one or two decades, although they believe promising potentials remain for improving productivity from the application of known technology and from new technology now in the research and development phases. On balance, however, they indicate that the biological realities suggest a slowing in the rate of productivity growth for most crops in the future and express similar concerns about productivity in the livestock sector.

Peterson has pointed out that total factor productivity in U.S. agriculture did not start growing in a substantial way until the 1940s, despite the fact that our research, teaching, and extension infrastructure was put in place in the late nineteenth century. The petering out of productivity growth in recent years suggests that a technological "epoch" is playing itself out until (and if) a new burst of innovations come on the scene. The truth of the matter is that we have only a weak conceptual and empirical understanding of the technological transformation through which U.S. agriculture has passed. Hence, little basis exists for knowing what to expect in the future.

The Shift to Floating Exchange Rates

The rules that have governed trade relations among nations in the post-World War II period were largely established by the Bretton-Woods Conference of 1944. At this conference the industrialized western countries under U.S. leadership established an elaborate system of trade, tariff, and financial arrangements that in its broad outlines lasted through the early 1970s. Central features of the system included reliance on fixed exchange rates and a number of reserve currencies, the most important of which became the U.S. dollar. In its role as supplier of the major reserve currency, the United States ran a persistent deficit in its balance of payments, collecting seigniorage in the process (Grubel).

This system encountered periodic difficulties as one country or another got out of adjustment, but for the most part it served the developed countries of the world reasonably well. World trade grew at a faster rate than world gross national product (GNP), and a growing interdependence among countries evolved, especially among those of the industrialized West.

As inflation picked up in the U.S. economy during the late 1960s and early 1970s, the U.S. dollar became increasingly out of line with the currencies of its major trading partners, and the deficit in the balance of payments grew increasingly larger. In August 1971 the dollar was devalued in relation to gold by 8% and again in February 1973 by another 10%. In the process the United States closed its gold window. De facto generalized floating among the industrialized countries was adopted in March 1973.

These successive devaluations of the U.S. dollar and the shift to floating exchange rates ended a rather long period of discrimination in economic policy against the agricultural sector (Schuh 1974). An overvalued currency is in effect an implicit export tax that, depending on the elasticity of foreign import demand and the elasticity of domestic factor supplies, has its incidence on the exporting sector. When combined with the tight monetary and fiscal policies designed to stem the gold outflow and control the balance of payments deficit, the result was a severe squeeze on agriculture, at the very time it was already experiencing a considerable adjustment problem due to the adoption of new production technology and substantial investments in nonhuman capital.

Changes in Our International Environment

In addition to the shift from fixed to a system of floating exchange rates, there have been a number of other important changes in the way the United States relates to the world economy. In the first place, the United States has become a great deal more dependent on its external sector. The share of exports in the total economy has doubled in the last fifteen years, and the share of imports has doubled in just seven years. U.S. exports and imports are each currently about 7% of total GNP and are still rising, putting them only slightly below the same ratios in Japan and in the European Common Market as a group, which are about 9% and fairly stable (Bergsten and Cline). In addition, about one-third of the profits of U.S. corporations now derive from overseas activities, primarily from foreign direct investments. Bergsten and Cline argue that if these profits are taken into account along with trade, the U.S. economy has probably become more open in quantitative terms than Japan or than western Europe as a unit. Moreover, the United States already imports more than 50% of nine of the thirteen industrial raw materials required by the domestic economy.

As one aspect of this general opening of the economy, U.S. agriculture has become more closely integrated with the world economy, especially on the export side. The export coefficient for agriculture doubled between 1950–53 and 1970–74 (Brandao and Schuh). At the same time, other countries have become increasingly dependent on the United States as a source of supply for grains. Although the United States has been an important and growing source of supply throughout the post-World War II period, it became of major significance in the early 1970s (Brandao and Schuh).

A third, and perhaps the most important, respect in which U.S. agriculture has become more strongly linked to the world economy is through the increased importance of agriculture in the trade balance. Although little recognized in contemporary discussions of trade and trade problems, there has been a major shift in the structure of U.S. trade, with the result that agriculture now makes a major contribution to the trade balance. The United States was a net importer of agricultural products in 1920–62; only in the mid-1960s did the trade balance for agricultural products turn positive and now has grown successively larger. On the other hand, a deficit in the trade accounts in nonagricultural products began to emerge in 1968 for the first time since 1930 (USDA).

The deficit in the trade balance of nonagricultural products literally burgeoned in the period 1971–74. At the same time, the surplus on the agricultural trade account also burgeoned. In 1973 that surplus was more than sufficient to offset an $8 billion deficit in U.S. trade in nonagricultural products. In 1974, it was just $3 billion short of offsetting an almost $15 billion deficit in trade in nonagricultural products, and in 1975, the $12.4 billion surplus in the agricultural trade accounts contributed mightily to the record $11.1 billion surplus in total trade accounts.

This change in structure of U.S. trade is of major significance to the U.S. economy. It imposes an important constraint on our economic policy vis-à-vis agriculture, while at the same time making both the agricultural sector and the general economy subject to shocks from the agricultural sectors of other countries.

The final significant change in the international environment is the increasing demand by the LDC's for a new international economic order. Encouraged by the success of the Organization of Petroleum Exporting Countries, these demands constitute a program for structural change in the system of trade and international relations among countries that was originally designed by the West. The argument of third world leaders is that the prevailing system is exploitative, functions to preserve the economic dominion of the West, and has prevented the nonindustrialized countries from developing. Their desire is to use trade to attain political objectives and to redistribute the world's income and resources in their favor.

Implications

There are six major implications of these changes that I would now like to address.

(*a*) The secular income problem in agriculture is now largely behind us. The emerging equilibrium in the labor market is of major significance in this respect. When this equilibrium is combined with the decline in the rate of productivity growth, the release of most of the idled land back to production, and the shift to the right in the demand for agricultural pro-

ducts as a result of devaluation, the result is an almost total disappearance of the excess capacity that existed at prevailing price ratios for such a long period of time. (For a more detailed discussion of this development, see Council of Economic Advisers 1975, chap. 6.)

The conditions of product supply have also undergone important changes, determined in part by changed conditions in the factor markets. With labor dammed up in agriculture and up to one-sixth of farm land withheld from production by agricultural policies, output was in the past fairly elastic in response to rising prices. Land could be released to production, labor could be more effectively utilized, and output could be expanded fairly easily. This is in part what happened on the occasion of the first post-World War II food scare in the mid-1960s.

That degree of flexibility on the up side no longer exists. The land in retirement under government programs has all been released to production except for that under long-term contracts. To the surprise of many, only about 37 million of the 60 million acres in retirement actually came back into production. In addition, agriculture now has to bid against the nonfarm sector to bring forth a larger supply of labor services, in contrast to just slowing down the rate of outmigration, as was the case in the past. This combination of a positively sloping supply curve for the two primary inputs, land and labor, suggests that sudden shifts to the right in the demand for agricultural output will be reflected in higher product prices. Much of the previous flexibility on the upside has been lost, at least when evaluated in terms of current input use.

On the down side, however, flexibility has probably been gained. A larger share of total farm inputs now comes from the nonfarm sector. Farmers are particularly responsive to the relative price of these inputs, with the result that declines in farm prices will result in a reduction in their use. Similarly, at least in nonrecession periods, it will probably be easier to shift labor out of agriculture in response to a decline in relative prices. The agricultural labor force makes up a smaller proportion of the total labor force than it once did and has also become more closely integrated into the nonfarm labor market.[4]

[4] The real income per capita from nonfarm sources increased markedly for farm operators after 1960 (see Gardner).

Overall, there has probably been an increase in the short-run supply elasticity of U.S. agriculture due to the increased importance of purchased inputs and the higher level of education of the labor force that increases farmers' ability to deal with disequilibria (Schultz). To the extent that asymmetry exists in supply response, the rigidity may now be on the up side rather than on the down side.

None of this is to deny that there still might be income problems in agriculture in response to short-term imbalances. However, it would appear that these would be of a transitory nature, and not the secular problems experienced in the past.

(*b*) The management of agricultural policy will be more complex. The evolution to a more open economy and the shift to floating exchange rates makes the management of economic policy a great deal more complex, if for no other reason than that there are more variables to keep track of and more policy instruments to manage. With floating exchange rates there are rather complex interactions among domestic monetary policy, the exchange rate, and the competitive potential abroad. An increasing tightness in monetary policy, for example, will attract a larger capital inflow, other things being equal, due to the rise in interest rates that it implies. The larger capital inflow, other things being equal, will raise the value of the dollar and in turn reduce the competitive potential on the trade account.

Similar considerations apply to the monetary and trade policies of other countries, especially those of major U.S. trading partners such as Japan and Germany. If they should pursue tighter monetary policies, the result will be to weaken the dollar relative to their respective currencies, thereby putting U.S. export products such as grains in a stronger competitive advantage vis-à-vis domestic production.

These interdependencies mean that agricultural economists have to give greater attention to monetary and fiscal policy if they want to understand developments in the agricultural sector and to make useful forecasts of trade and other variables in the economy. Moreover, being sensitive to domestic monetary and fiscal policy is not enough; concern about policies in other countries is needed.

A further complication arises from the importance of agricultural trade in balance of payments. The exchange rate now has to be treated as endogenous with agricultural trade.

Weather-induced fluctuations in foreign import demand can affect the exchange rate and, in turn, influence the allocation of exports among alternative markets. Equally as important, if controls should be imposed on agricultural exports, the value of the dollar may decline in international markets. This will raise the prices of U.S. imports. If such import controls are imposed under the guise of controlling domestic inflation, they will be shortsighted, although that does not deny the validity of such interventions under certain circumstances. Obviously, both the distributional and growth consequences of a decline in U.S. food prices are very different than those from a rise in prices of import goods.

The increased complexity in the management of economic policy is not necessarily a disadvantage, although it obviously increases the scope and magnitude of information and research needs for decision making. The obvious corollary of the increased complexity is an increase in the degrees of freedom in the management of policy, since there are more variables to do the adjusting. Moreover, the consequence of an increase in the number of variables that can adjust is that a given shock to the system is diffused on a much wider basis. For example, if world trade was free and all exchange rates were floating, a short fall in grain output in another part of the world that led to a large increase in demand for U.S. exports would bid up the value of the dollar on international exchange markets. This would make U.S. exports more expensive to other countries, causing a reduction in the quantity demanded.[5] In that way the cost of the short fall would be spread more widely around the world and not be limited to just a small number of exporting and low income countries, as in the recent past.

The problem is that we are far from having completely free trade and generally floating exchange rates. As Johnson has pointed out, much of the instability in international markets in recent years was due to barriers to trade and rigidities in domestic agricultural policies. But that only points up the importance of the current round of multilateral trade negotiations in which the United States is attempting to have agriculture included in the next round of trade liberalization. It also points up the importance of engaging the LDC's in a constructive dialogue so that they can be induced into more liberal trade policies. Without such developments, the U.S. food and agriculture sector will continue to be buffeted by shocks from the international economy unless we go back to a costly program of grain reserves.

(*c*) The price of food to the U.S. consumer will be determined in part in international markets. The increased openness of the U.S. economy, especially for agriculture, means that the price of food at home will be determined in part by international markets. No longer will a major share of the benefits of technical change in agriculture redound directly to consumers in the form of lower food prices due to an inelastic aggregate demand for food. Although the foreign demand for output is not perfectly elastic, it does appear to be on the order of -5.0 or -6.0 (Tweeten). The growing share of U.S. output going abroad makes the aggregate price elasticity of demand for U.S. output larger. Hence, domestic consumers will tend to benefit more from the increased export capability that technological change in agriculture represents than from an immediate decline in relative food prices.

Similarly, to the extent that there is a world food problem, consumers will share in it in the form of higher food prices, just as in recent years. Export controls and other trade interventions could keep consumers from bearing the costs directly in the form of higher food costs. But such interventions would raise the price of U.S. imports through their effect on the exchange rate, so the income loss would be experienced in any case, although as mentioned above with quite different income distribution consequences.

(*d*) U.S. consumers now have a vested interest in agricultural research and development abroad. Food prices in the United States, to the extent they are determined by the price of raw agricultural products, will decline only as the world supply of agricultural output increases relative to demand, with the important caveat about trade restrictions noted above. Despite the size of U.S. agricultural exports and technological superiority, the United States alone cannot lower world food prices. Hence, U.S. consumers now have an interest in improving world agriculture and in bringing world population growth into balance with potential food supplies. This interest should no longer derive solely from a feeling of benevolence toward the world's

[5] It would also lower the domestic price of imports, thereby helping to offset the rise in food costs that might result from such a shock.

poor, but because it is in the best interest of consumer groups.

The technological gap between U.S. agriculture and that in the LDC's is sizable, so there is much potential to be exploited in increasing world food output. Investments in agricultural research in other lands will be the key, but activities should not be limited to that. We also have a vested interest in training the people required to develop the indigenous institutional capability in other lands and in improving international capital markets and the flow of capital to agricultural development in the LDC's.

(*e*) Domestic agricultural research policy needs to be revamped. Two aspects of domestic agricultural research policy appear to be in need of change. The first is the balance between basic and applied research. With the apparent realization of much of the potential from existing scientific and technological know-how, the obvious need is to put a greater emphasis on basic research. Yet the current emphasis on accountability and the financial pressures on educational and research institutions puts greater emphasis on applied research. This emphasis needs to be changed.

Equally as important, new means of financing agricultural research need to be devised. The more elastic demand for agricultural products that the increasingly open economy brings with it confers on land owners and other resources that are inelastic in supply a larger share of the benefits from domestic research and development (R&D). Under these conditions, it is not likely that a consumer-dominated body politic will be willing to support domestic R&D as they have in the past.

Given that agricultural land owners and producers will now receive a larger share of the benefits of domestic R&D, a case can be made that they bear a larger share of the costs. The long-used check-off system used to finance cotton research is one means of solving this problem, as is the recent legislation on poultry and egg promotion and beef promotion. Alternatively, a land tax might be devised for this purpose, since an important share of the benefits of technical change will be realized in the form of higher land values. Still another means would be by way of an export tax, although at the present time the Constitution prohibits such a tax.

(*f*) New sources of productivity growth for labor need to be identified. Increases in labor productivity in agriculture are important if wage rates and the income of farm people are to continue to increase. Similarly, increases in productivity in the economy at large are important if aggregate growth rates of the past are to be sustained. The decline in outmigration from agriculture has implications for both of these.

For agriculture, it implies a decline in the rate of productivity growth for that sector. Growth in labor productivity in U.S. agriculture has been unusually high throughout most of the post-World War II period. It is not difficult to understand why. Output has been expanding steadily, the labor force has been declining, and other nonlabor inputs such as fertilizers have increased substantially. As a result, factor proportions have shifted markedly. The land-labor ratio has risen; the physical capital-labor ratio has risen, the fertilizer-labor ratio has risen; and society has imbedded more human capital in labor in the form of higher levels of education. It is little wonder that labor productivity has grown so rapidly.

The consequences of a decline in the rate of outmigration will be equally multifaceted. In the first place, the land-labor ratio should change more slowly. Additional mechanization can and undoubtedly will take place, although it is important to note that agriculture is already one of the most capital-intensive industries in the economy. The use of other inputs, such as fertilizer, can also be increased, but in this case the factor proportions will probably change at a slower rate in the future. As noted above, there is evidence of diminishing returns against land in the application of fertilizer. In summary, the expectation is that there would be a decline in the rate of growth of labor productivity as the rate of outmigration declined.

The data suggest that there has been a marked decline in the rate of productivity growth over the years, just as the analysis suggested (table 1). The time periods were chosen so as to coincide with observed changes in the labor market. The rate of outmigration started to decline in 1965; by 1971 it began to flatten out even more.

This decline in the growth rate of labor productivity is one explanation for the leveling out of the growth rate in total factor productivity in agriculture. It has been reinforced, however, by the decline in the growth rate of crop production per acre—or land productivity, a decline even more pronounced than

Table 1. Growth Rates (%) in Productivity of Land and Labor, Selected Periods, 1950–75

Period	Farm Output per Unit of Total Labor	Crop Production per Acre
1950–65	10.8	3.7
1965–71	6.9	2.0
1971–75	2.0	0.4

Source: Synthesized from data in Council of Economic Advisers 1976, tables B-84 and B-87.

the decline in labor productivity growth. Together, these data give one cause for concern about the potential for productivity growth as a source of output expansion in the future, unless there should be a major breakthrough in production technology.

The decline in outmigration from agriculture also has implications for the economy at large. In the past, an important source of aggregate growth in the economy has been the reallocation of labor from the low productivity agricultural sector to the higher productivity industrial and nonfarm sector (Denison). Given the magnitudes of the labor transfer during the post-World War II period, the gains from this source have been sizable. With the transfer process apparently nearing an end, this source of productivity growth for the economy at large declines or disappears.

This development points up the importance of productivity growth in other sectors of the economy if aggregate growth rates are to be sustained. The service sector, where some 60% of the labor force is now employed, is a strong candidate, and the growing government sector is especially important. The payoff to society of reducing the high level of unemployment among blacks in the 16- to 24-year old age group also promises to have a high social payoff.

Of more direct relevance to food and agriculture, productivity in the processing and distribution sector can be an important source of growth and a means of lowering food prices to consumers. Sixty percent of the food bill is provided for goods and services from this sector. Labor practices now impede the adoption of such technologies as the central boxing of meat, and consumers resist computerized checkout at supermarkets, both of which can be important sources of productivity growth.

As these examples indicate, the sources of growth are not lacking. They just will be different in the future than they have been in the past. But society does need to seek them out, and when changes in labor practices and other rigidities are needed to bring them about, those changes need to be made.

Emerging Institutional Challenges

The new macroeconomics of U.S. agriculture involves a decline in the outmigration from agriculture, a leveling out of productivity growth, the evolution of the U.S. economy into a more open world economy, and changes in the international environment. The institutional challenges to us as a nation and to us as agricultural economists are great.

The first challenge is to be successful in negotiations for freer world trade. The current Tokyo round of multilateral trade negotiations is potentially more important to us than the previous Kennedy round, especially if progress is made in liberalizing trade in agricultural products. If we can sustain the past movement towards freer world trade and at the same time extend the domain in which exchange rates float freely against one another, large steps will have been taken towards the much sought-after goal of world food security and without the political problems of a government-managed grain reserve.

Under such a system exports on the margin should shift sharply from one country to another in response to changes in exchange rates and in internal prices in countries around the world. Therefore, a major challenge in such a system will be to maintain confidence so that individual countries can depend on having open access to markets, either as buyers or sellers.

The evolution of such a system requires the introduction and development of new institutions that provide a means of making the emerging world economy work more efficiently. A more efficient system of monitoring world agriculture and diffusing the resulting information to the world economy is needed, as are improved marketing arrangements. Steps also should be taken to improve the functioning of the international capital markets, with all the political difficulties that that entails.

Clearly, the thrust of these suggestions is in the direction of strengthening an international market system to better serve the world economy. To some that may sound utopian; to others it will sound imperialistic. The truth of

the matter, however, is that important strides have already been taken towards an international market economy.

Domestically, we face challenges in both research and teaching programs. On the research side, there is not an adequate institutional capability to do the research necessary to understand world agriculture. Researching and understanding international trade per se will not be sufficient. To shape and reshape a continuously rational policy more understanding is needed about world agriculture and the forces that shape it, how foreign economic policies are shaped, and how changes in those policies influence international commodity and capital markets and in turn U.S. agriculture.

Changes are also needed in the educational program. Students need to be given stronger training in macroeconomics and in the aggregate aspects of agriculture. Their training also needs to be strengthened in trade and in the economics of an open economy. Finally, they need some familiarity with world agriculture and with the economic and other forces that shape foreign agriculture.

Our task in public education is no less great. The educational needs of the adult population are very similar to those of the students. In addition, some of the major policy choices to face in the years ahead have to do with the U.S. role in the world economy and how we relate to it. Rational policy will evolve only through an informed body politic.

Some Concluding Comments

Agricultural economics is by definition a sectoral discipline, which is both a source of strength and a source of one of the major weaknesses. The former is so because it has caused specialization in understanding the problems of a single sector of the economy. Our initial start in dealing with the art and science of farm management gave a strong underpinning in the microeconomics of the sector. The close association with correlary disciplines in the various schools of agriculture, which have for the most part been our academic homes, gave a perspective that few fields in economics have had.

At the same time, a sectoral emphasis has caused neglect of the linkages of agriculture with the rest of the economy and underestimation (or underemphasization) of the interrelationships between agriculture and the larger economy. Agricultural economics earned its spurs and has made most of its contributions to science and knowledge with its work at the microlevel. If there has been one major failing over the years, it has been this failure to grasp fully the macroeconomics of agriculture.

Agricultural economists have made important contributions to economic theory. For example, they have contributed as much to development economics as has any other subdiscipline of economics. They have contributed to methodological improvements and have also played an important role at the national policy-making level.

We are now faced with new challenges. The domestic structure of agriculture is changing, especially in the way that agriculture is linked to the nonfarm sector and in the contribution that agriculture makes to the larger economy. At the same time the U.S. is increasingly linked to a large and rapidly changing world economy. Events in the rest of the world are now as important to the strength and vitality of the food and agriculture sector as are developments in the domestic economy.

It is now almost an imperative that we give strong macroeconomic training to students, that we challenge them to know more about world agriculture and world economic development, and that we develop a research capability that will enable us to provide useful analytical and empirical inputs into the policy-making process and to effectively discharge larger educational responsibilities to U.S. citizens. Our challenge will be to do this without weakening the microeconomic work that is so much a part of tradition and that can serve so well in developing the macroeconomic theory and in doing the macroeconomic work that is before us.

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A Contemporary Political Economy of Family Farming

Paul W. Barkley

Making sense of two ill-defined concepts is not an easy task. It must be undertaken, however, because people inside and outside of agriculture are asking about the family farm and how it relates to the political economy. The source of confusion centers on the changing organization of agriculture and changes in the control of resources traditionally used by North American farmers to produce crops and livestock products. It is suspected that this changing control is bringing considerable change in output, efficiency, and the distribution of spoils in the industry, but no one yet knows if this is so.

The fundamental changes in U.S. farming need not be recounted. Farm numbers have dropped, nonfarm capital has substituted for home-grown capital, the use of stock resources has replaced the use of flow resources, and formal information-gathering techniques have substituted for informal gossip. All this is known; some is only partially understood.

Similarly, the increased centralization of economic activity, the increased interdependence between the agricultural and the nonagricultural sectors, the resurgence of world trade, and the apparent worldwide fuel crisis are familiar attributes of the contemporary political economy. They impinge upon agriculture, but they need not be described here. It seems appropriate to turn directly to the main problem. How is the family farm related to the contemporary political economy and what relationships exist between economic society and the agricultural industry? This question is addressed by elaborating some definitions, commenting on production, exchange, and distribution within agriculture, and discussing agriculture's place in the political economy.

The Family Farm

Although there were family units producing agricultural products in antiquity, the family farm as we know it likely traces its origins to the enclosures. The enclosures broke the small fiefdoms of Europe, played a necessary role in releasing laborers for industrial pursuits, and gave land to individuals who could till it as they wished without subservience to the will or needs of the ruling class. In the eighteenth century, Thomas Jefferson developed ideas about the virtue and importance of men working land that they themselves possessed. Such orgaization brought incentive to produce, allowed individual freedom, and was expected to yield better husbandmen and citizens.

Like the world around it, the family farm has changed. A century ago, it was a place where a family utilized its own resources to produce the products needed to maintain itself and the farm firm. If surpluses were produced, the farmer entered into exchange agreements by selling crops and buying capital equipment, staples, and other consumer goods. With the advent of mechanized equipment and the subsequent demise of the horse, the family had extra labor—labor that either fled to the city or was utilized through expanded farm operations.

Even two decades ago, a family farm was a place where a multigenerational family could utilize its own resources to initiate and complete a production cycle. The family controlled the resources, made the decisions, and enjoyed or suffered the consequences. Decisions about producing the nation's food were dispersed among millions of small family units. Now the farm family is not expected to own the farm's resources nor is it expected to

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supply the labor needed to operate the farm. In a recent, highly overdramatized article appearing in the revived *Saturday Evening Post,* Paarlberg defined the family farm as one "on which the greater part of the labor and decision making is supplied by the farmer and his family" (pp. 42–43). When accompanied by data saying 95% of U.S. farms qualify as family farms and that these account for two-thirds of the nation's total agricultural output, a comforting picture of families working together on independent units appears.

Paarlberg's definition, though somewhat standard in technical as well as popular writing, is extremely deceiving. It makes no provision for income goals or efficiency in resource use. There is room for suspicion that defining family farms as good, then declaring that 95% of the nation's farms are in this class, imputes goodness to a situation that includes much that is bad. Indeed, there is poverty, inefficiency, illiteracy, and immobility among Paarlberg's 95%. His definition draws attention away from this. The family farm as defined is apparently desirable but only on ethical, moral, and romantic grounds—issues that have been systematically trained out of agricultural economists and left in the realm of politics, literature, and poetry.

Political Economy

The definition of political economy is less romantic but no more secure than that of the family farm.[1] Agricultural economists are asking for a return to this branch of the discipline, but what do they have in mind? Are they asking for a return to the political economics of the classical economists, or are they asking for a return to the 1930s and 1940s when agricultural economics and agricultural economists had a stronger hand in determining the nation's agricultural policy? One must presume the former since only through it can much discipline be brought to the latter.[2]

What is the traditional political economy? The common feeling suggests that political economy is broader than just economics. It includes some notion of how policies affect economic affairs and how, in turn, economic affairs bring about changes in policy.[3] In the early nineteenth century, Ricardo was practicing political economy when he observed the effects of the Corn Laws on the incomes of people, their employment status, and the value of land. Ricardo used this observation as a springboard to clarify the theory of rent. In this case, a public policy led to elaboration and explication of economic theory.

A century later, the farm policies of the New Deal would have qualified as political economics on the same grounds. These were policies born of privation in the agricultural industry. The economists who worked with them came to understand the theory of the firm and eventually saw the need for an intensive modern study of farm management. They, no less than Ricardo, were practicing political economy when they extended theory after observing the consequences of a policy problem.[4]

The massive sales of wheat to communist nations, the public interest in private land, the world food shortage, and the distressingly high fuel costs may also bring the need for inquiring how exogenous influences affect agriculture and how happenings within the industry can impinge upon the outside world. If political economy is this broader view, surely it is a good thing.

However, political economy as seen by Ricardo, Malthus, Senior, Say, and Mill was more than a two-way inquiry regarding the causes and effects of economic policy. It was the general study of production, exchange, and distribution conducted in a society characterized by three distinct classes of people. With boldness that few of us would dare, Adam Smith divided economic society into classes of workers, capitalists, and landlords. Ricardo accepted this division and went on to say that "to determine the laws which regulate distribution among these classes is the principal problem of Political Economy" (p. 5).

The mainstream of economic thought that led from Smith through the classicals then on

[1] Contemporary definitions of "political economy" are hard to find. Reflective comments on the theme can be found in Jalladeau, G. Schultz, and Heilbroner.

[2] One of the more urgent pleas was made by Breimyer.

[3] Interestingly, Alfred Marshall took the opposite view. After defining economics to be "a study of the economic aspects and conditions of man's political, social and private life; but more especially of his social life" (pp. 42–43), Marshall suggests that economics "shuns many political issues which the practical man cannot ignore: and it is therefore a science, pure and applied. . . ." From this, Marshall draws the conclusion that the discipline "is better described by the broad term 'Economics' than by the *narrower term* 'Political Economy' " (emphasis added).

[4] Perhaps the best example of this was provided by T. W. Schultz.

through Marshall, Pigou, and into various U.S. traditions developed a revulsion for classes in society, so these were hidden behind a transparent veil called "factors of production." Class distinctions are still avoided by depending upon the categorization of factor inputs, and questions of how income is divided among people are almost always avoided by asking only how income is divided among factors. Had the discipline retained the class distinctions of the classical definition, the makeup of our profession and our collective inputs into policy formulation would be considerably different.

Production, Exchange, and Distribution

If political economy does dictate that economic analysis be conducted on a three-way basis, it makes sense to examine agriculture in each of three contexts: production, exchange, and distribution. Most could be said about production because the dramatic changes in agriculture have stemmed from changes in production practices, most having come in response to major changes in technology. The three-field system, the steel plow, the internal combustion engine, and the mechanical cotton picker each revolutionized at least a part of the industry.

Agricultural economists have done a capable job of inquiring into production. They have consistently recommended that inexpensive inputs be substituted for expensive ones and have stressed the trade-off between high variable incomes and low stable incomes.

Family farmers, no less than corporate farmers or subsistence farmers, have been apt students for and of economists' efforts. They have substituted capital for labor and have fine tuned along a continuum that stretches from complete specialization to extravagant diversification. U.S. farmers are to be congratulated for behaving as economists suggest they should in always searching for new and inexpensive ways to do old and expensive chores; they have learned to substitute science for art. In the present context, little needs to be said about the production process, political economy, and family farming. Production is interesting primarily because changes in it have a demonstrable effect on the process of exchange and on the institutions surrounding the distribution of income among factor owners.

All farmers enter into exchange relationships on either side of their production activities. Exchanges on the input side have increased in number and have become more complicated as various forms of productive capital have left the direct control of the family farmer and now reach him only through organized markets. Changes on the product side are no less intense because farmers have become increasingly remote from final consumers and have relinquished control over several productive activities. A class of intermediaries has sprung up to perform low-level processing functions that alter the form of agricultural commodities to fit consumer preferences. Farm operators, especially those in the family farm class, have continually heaped wrath on these processors, but clearly processors perform functions that the consumer is willing to pay for and that the farmer is unable to perform. The wrath is surely unwarranted, but it has become a part of the propaganda used to justify the family farm.

Processors of agricultural products can be used as a vehicle to point out one of the many paradoxical asymmetries evinced by farm operators as they consummate exchanges. The farmer has insisted upon high quality standards for purchased inputs. While noncertified seed can be purchased in voluntary exchanges among neighboring farms, certified seed must be of a specific high quality, and this quality must be guaranteed by the seller. Similarly, mixed feedstuffs for animals must be clearly and honestly labeled, and the chemical analysis of fertilizers must be shown on containers in which these inputs are sold. Since individual farmers have little market power, they have banded together to obtain legislation insuring the quality of inputs. In cooperating, the individuals have abdicated some of their independence. They have paid for it in the form of higher input prices, but the uniformity of the input coming with mandated quality requirements has apparently been worth the price.

Similar forces have motivated the purchasers of many farm products. Processors, like farmers, can be more efficient if they have regular streams of uniform raw materials (inputs) coming into their plants. About twenty-five years ago, many processors of farm products began to reach back to the farms in an attempt to make the flow of farm products regular and to insure that the products were uniform in size, shape, color, and quality. This

made as much sense for the processor as input quality control had made for the farmer. In order to achieve certain gains in efficiency, processors had to insinuate themselves into production processes carried out on individual farms and insist that inputs of certain kinds be applied at certain times and that certain quantities of crops be delivered on certain days. The processor had to assume control of production. This was done in the era of vertical integration that swept through the vegetable, fruit, poultry, and livestock enterprises in the 1950s.

Vertical integration was unpopular with farmers. They apparently resented the encroachment on their capacity to make decisions and, ostensibly at least, would rather have maintained the capability of using the wrong inputs to produce an inferior product for sale on a day when it could not be processed. At the time it was happening, the erosion of this opportunity to err was viewed as precursor to the demise of the family farm. The response was clamorous with major farm groups as well as individual operators castigating processors for doing what farmers themselves had already done: taking steps to insure the quality and quantity of a factor input.

The concept of the family farm did not vanish with the advent of vertical integration. Instead, it adjusted to accommodate the new form of business organization. After vertical integration took hold, the farm family became a labor pool using resources controlled by nonfarm decision makers. Rather than threatening the family farm, integration of production and sale activities seems to have benefited those who at first condemned it. Successful farm operators accepted the superior managerial skills of the processors' fieldmen as part of the integration process. Now, the contract that allows involvement in a vertically integrated production process is almost a property right and has taken its place along with land ownership, water rights, peanut allotments and the conservation reserve as part of the farmer's bundle of rights.

But the asymmetry of these essentially bargained exchanges on either side of the production process has escaped attention. The psyche of the farmer says that he is free to exist as a small unit and to make his own decisions. Society has indulged him in this fancy. Apparently this ideological bent allows the farmer to impose rules on the suppliers of his inputs, but it does not allow the purchasers of his products to similarly impose on him. Here, perhaps, is the making of a noteworthy study of the farmer's role, his self-image, and how these characteristics affect his behavior in exchange.

The third dimension of classical political economy relates to distribution. Of all the themes treated by economists, this is surely the most evasive and consequently it has received very little analytic attention. Robbins' modern definition of economics contains no hint about distribution, and the marginal conditions of maximum welfare abstract from the issue to the point of threatening their own internal compatibility. Marginal analysis when conducted in a partial equilibrium framework is strict: distribution is determined by factor rewards determined by a factor's contribution to the production process. Under this scheme, the distribution of family income depends on the number of factors a family controls. This view of distribution is comforting to an analyst. It is objective, rigorous, free of value judgment, and provides access to numerous analytic hypotheses; however, it has a serious flaw. While it can lead to determining when distribution is not in accord with the rules of the margin, it cannot lead to prescriptions about what incomes should be. The same market mechanism that capably allocates resources does nothing to insure that a resource in its highest and best use will receive sufficient rewards to maintain itself.

For a time in the late 1960s, economics and agricultural economics came out of the distributional reverie supplied by the marginal analysis and began to describe poverty in agriculture; the conclusions were not highly rewarding. These agricultural economists proved only that the poor in agriculture were poor because they could not command sufficient resources to be wealthy.

Many agricultural and farm programs began as income programs intended to buoy the returns to an economically beleaguered industry. However, given the peculiar institutional relationship that exists between the farm family and its resources, the labor share has seldom been the residual claimant of record. Net returns in the short run—quasi rents in the parlance of rent theory—have been imputed into the value of fixed resources. Moreover, family labor has likely been dreadfully underpriced, exaggerating the claims other resources have on the farm's returns. The truly skilled manager who has been able to keep a

small family farm solvent only through ingenious manipulations of factors may find that when external forces impinging on the farm's economy finally require liquidation, the skill that kept the farm running is not rewarded. The net returns to the operation—operator and all—are imputed to land and other fixed factors. The only access the farmer has to rewards for his flow of skill is to sell the stock resources that have been the object of that skill. The problem is especially distressing in cases where the land is not owned by the operator. The superior skills of the operator become high land prices that eventually accrue to the nonfarming landlord.

In sum, political economy, as traditionally construed, is a discussion of production, exchange, and distribution. While the field of study has many interesting facets, and these form interesting interfaces with the family farm, a discussion of the contemporary political economy of family farming is not a particularly fruitful exercise when carried out on a farm-by-farm basis. The real value of studying the two in the same context comes from society's point of view.

The Social Significance of Family Farms

Examining the social significance of family farms requires a modification in approach. Instead of concentrating on the family as a labor pool and decision-making unit for a single farm, the focus changes to the way in which factors are held—the property rights possessed by the farmer. This nation has always placed high regard on private ownership of land and other natural resources. The private ownership of land, however, opens considerable opportunity for society to exploit the owner of the resource. Contemporary writers are quick to point out that the family farm is "resilient" and able to withstand low prices, poor weather, and inferior inputs. While it is true that individual farms and U.S. agriculture as a whole weathered the economic catastrophe of the 1930s without significant reductions in output, it is misleading to credit the industry for this occurrence. More accurately, society found it easy to exploit the people and resources committed to farming.

In contemporary society, the small holder who uses his family's labor in conjunction with his fixed capital and land is in an ideal position to be exploited. His variable costs are low and, once a crop is in and a biological process started, the costs of continuing the process until harvest are extremely low. Low variable costs provide an incentive to maintain output even if product prices fall to disastrously low levels. After harvest, fixed costs must be paid, but even they are subject to deferral. Thus, the nation's family farmers consume the depreciation on all forms of capital, pay themselves extremely low wages, and even defer payment of taxes knowing that this deferral can be continued for two or more years before the threat of foreclosure emerges. During this time, production continues, the family farm appears to prosper, and the nation has its food.

This elementary point regarding continuation of production is made in all basic textbooks. The more important relationship between the economic organization of the agricultural industry and the economic performance of the society is too frequently ignored. Stability in the general economy is not insured by keeping agriculture resilient. However, reasonable stability in the food supply is. To date, agriculture has been kept resilient by maintaining or encouraging small units on which operators have relatively high equities and relatively low variable costs. The family farm is the ideal form of organization for providing this combination of resource control and resilience. An agriculture organized in this fashion becomes a perfect shock absorber for not only its own errors but also for those imposed upon it through other forces in the economy.

Resource control in agriculture is changing. Vertical integration changed the control of inputs on (usually) small parcels of land. Land ownership patterns are changing, the threat of corporate management has been growing in intensity, and control of credit has become awesome both through its concentration and its archaic rules designed to protect the banker rather than his customer. With all these forces operating to fragment control of agriculture's productive resources, the legitimate question becomes: who is in charge? Like the farmer's relationship with the processor, his relationship with the fragmented controllers of factor inputs is asymmetrical. Any one "controller" can order production stopped, but no one controller can order production to start. The farmer becomes more than risk taker and laborer; he is the initiator who must poll various resource controllers and solicit their coopera-

tion in an increasingly joint venture. This role of the farmer as a multidimensional negotiator is not understood nor is it, I think, being investigated with any degree of intensity.

The Consequences

Bringing these diverse themes together into a cohesive lesson for agricultural economists requires mixing economics with folklore and these in turn with an important part of the American political and agricultural traditions. It is relatively easy to comment on definitions. The definition of the family farm has changed in the past and is certain to continue to change in the future. Families will continue to work together and make decisions. The political economy of the decision-making process will also change as added segments of the agricultural industry are standardized, vertical integration continues to expand on the product side, and supply cooperatives continue to usurp farmers' decision-making power on the factor side of the production process. Even though negotiated and bargained exchanges will become fewer in number, those left will become more difficult to make. If agricultural economists continue to be involved in decision making, it will become necessary to learn whether twenty easy, daily decisions are, in aggregate, more difficult than a single decision that allows avoidance of the twenty! This sounds like a trivial exercise, but it has the makings of a fascinating riddle and may pave the way for extremely useful research regarding the relationship between the decision-making process and the allocation of resources on family farms.

But other problems intervene. Power is clearly being concentrated within the agricultural industry and the ancillary industries that supply agriculture with inputs and purchase its products. The Lorenz curve that results from plotting land holdings against farm size is creeping away from the diagonal as is the curve plotting farm receipts against farm numbers. Bigness is emerging. This nation indulges in another of its fantasies when forced to ponder the effects of this concentration of power on the organization of agriculture and the relationship between agriculture and the remainder of the economic system.

But the concentration of control raises legitimate fears. In concentrating, those who make decisions are removed from the resources and are likely to be motivated by the economic forces that influence firm behavior—product prices, profits, internal rates of return, and pay-off periods. If agriculture is organized on these lines, the great loss will not be the loss of moral and cultural virtues of family farms but the loss of the capacity of the small-holder system to maintain production in a time of economic adversity. An agriculture in which resource control is centralized may be more efficient, more productive, and more responsive to the demands of food consumers and may provide higher incomes to persons involved in the ownership of resources used in the production process. However, it does not have that most desirable of all characteristics: guaranteed stability in output.

In this setting it is legitimate to ask whether the family farm should survive with any more than a rhetorical dimension. It should because the social consequences of not having an exploitable food producing class are too high. If the institution is to be preserved, it will have to be preserved on noneconomic grounds.

One way to preserve the family farm is to make it the object of religious-like veneration among all citizens. Some careful distinctions will need to be made in such a movement. The object of veneration should not be the stolid simplicity of the man, woman, and pitchfork as in Grant Wood's painting "American Gothic," which gives virtue to the people who run the farm. The object in a present-day context will be the farm as a farm. Moreover, the adulation will need to be accorded the sole proprietorship in agriculture rather than just any sole proprietorship. Although the small farmer has much in common with the small restauranteur, the independent corner grocer, and the independent fuel dealer, society must concentrate with special attention on the farmer. He must plant and harvest each year, and society's stake in this process must not be confused with society's stake in the record shop, the back country lawyer, or the local Hallmark card dealer.

A Program of Work for Agricultural Economists

It would be foolish to recommend that agricultural economists, either individually or as a professional association, ignore the family farm or treat it as only a political or romantic

construct. If indeed 95% of all U.S. farms are family farms, the sheer force of their numbers dictates that members of this profession become aware of their existence and build them into research, teaching, and policy programs. This can be done in many ways, but some themes appear more important than others. The most important centers on the generality of the family farm. It is general in location (all parts of the United States have them) and quite often general in the sense that it produces a mixture of crops and livestock. The plea to inquire into family farms is a plea for generality among researchers. Researchers in agricultural economics have become extremely specialized, so much so that in pursuit of specialty many have lost sight of all but a few characteristics of agriculture or the role of agriculture in the economy as a whole. Our extremely awkward agricultural policy of the past decade is an outward manifestation of this loss of integration and purview. Four lines of research can be suggested to correct this problem.

First, the economic role of the family farm in U.S. economic society must be better understood. While intuition and the deductive logic of production, efficiency, and welfare economics tell us that the family farm is a good thing in terms of its ability to absorb adversity, there is no hard evidence showing how much adversity can be absorbed. Looking ahead to a world with high possibilities for unrest and instability, this kind of information would be more than just useful. The adversity absorption coefficient for U.S. agriculture could be found by close inquiry into cost structures, alternative sources of income, tax delinquency laws, bankruptcy provisions, and family income plans. Such studies should concentrate on the farms rather than on the individual enterprises. Society needs to know when its farms will shut down.

Accompanying this inquiry is a second theme, related to Ricardo's prime interest in political economy. How will income be distributed among those in agriculture as various shut-down points are approached? Although much economic research is related to and depends upon specific classes of resources, knowing the functional shares among those classes are not particularly revealing in the case of agriculture. The farmer, especially if he is made in the classic mold of the family farmer, is at once capitalist, land owner, and laborer. It does little good to know that two-thirds of the product (income) goes to labor if it is not known how an individual himself is distributed among the classes. What happens when returns to family labor drop to intolerably low levels while returns to capital remain high? What kind of income maintenance programs will need to be designed to keep appropriate sets of resources from being broken apart? Answering these questions will require extremely innovative research.

Third, the problem of asset control in agriculture is a pressing one. It is somewhat interesting to know whether assets controlled by the Boeing Company, the Coca-Cola Company, or Mutual of Omaha are any more or any less productive than those controlled in blocks suitable for 160-acre implements. It is more essential to learn about the institutions that govern the acquisition and the abandonment of control. These institutions will become important regardless of how resources are controlled or who controls them. Research into institutions affecting agricultural production is very tedious because only a few agricultural economists have the training or the patience to undertake it. The main body of institutional research in agricultural economics has emphasized the institutions surrounding natural resources, especially land and water. It will take some effort to transfer this skill to studies of institutions that affect labor, credit, managerial skill, and the exercise of power in market exchanges.

Finally, the agricultural economist must recognize that the family farm exists in a context that impinges upon the decisions made within the farm and the industry. Some agricultural economists should be asked to study this context and to inquire into the public benfits of the essentially private firm. The latter will be broadening if a handful of scholars are able to make progress in understanding the publicness of private enterprise. Perhaps the overextended specialization among us will weaken, and we will find ways to put our research to good use.

In this study of context there will be the utmost temptation to call in other disciplines to inquire into decision making, social significance, and the political acceptability of various family farm themes. At some point these temptations must be honored. For now, the economist has ample work within his own discipline. The economic problems should be understood before we submit to the difficulties of interdisciplinary research.

In sum, the family farm exists as an economic, political, and romantic entity in the U.S. economy. It will continue to exist in a political economy, and professional agricultural economists will be well served by looking at the whole farm from the point of view of the classical attributes of political economy. Moreover, these activities regarding production, exchange, and distribution will need to be addressed from some point of view other than that held by the individual farm operator, which is too specialized, too narrow, and does not lead to an adequate policy base. The social importance of family farms needs to be addressed. Society has a large stake in the institution and has maintained the institution by turning public vice into private virtue. The terms of this coexistence need explication. It is our job to bring substance to that view so that the family farm becomes recognized for its ability to absorb miscalculation and adversity and for its role in a confusing and fast-moving political economy.

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Agriculture in International Economic Relations

Thorald K. Warley

The systematic study of international economic relations has commanded increased attention in recent years among both economists and political scientists as the economic relations between nation states and groups of countries have intensified, changed in character, and generated a weighty set of new and complex problems. Matters pertaining to foodstuffs and other primary commodities are the subject of both unparalleled cooperation and dangerous frictions between members of the international community. Those involved in the conduct and the study of international affairs attach great weight to commodity policy issues in international economic relationships. Equally, a range of "external" considerations have been elevated in importance in national policy formulation for the agricultural and food sector. Thus, it is appropriate and timely that the American Agricultural Economics Association (AAEA) consider the subject of agriculture in international economic relations.

In a paper of tolerable length one can touch on only some of the more salient features of a subject of enormous scope and infinite complexity. I omit entirely any comments on the topics of world hunger and food insecurity, on the manifold interdependencies between energy pricing and world agriculture, and on the subject of "food power." My purposes are modest. First, I provide a short inventory of some of the more prominent characteristics of contemporary international economic relations. This serves as an introduction for some observations on the agricultural matters that are of importance in the economic and political relations between major groups of countries. Finally, I share with you some of my concerns about the participation of members of our profession in international commodity policy formulation and in conducting research and teaching in this area.

The Changing Character of International Economic Relations

Even the most casual observer of international affairs must have a sense that the world is in the midst of a vast historical transformation in security, diplomatic, and economic relations. Five characteristics of the changes that are afoot seem to have particular import for understanding the place of agriculture in international economic affairs.

First, as Cooper has noted, whereas strategic balance, territorial integrity, and ideological competition once constituted the main stuff of higher foreign policy, now foreign economic policy is the core of foreign policy. The world *problematique* is increasingly defined in terms of the economic relations between states, and its content is heavily weighted with such specific matters as trade and monetary arrangements, economic development and stability, supplies of food stuffs and raw materials, transnational production, claims on the resources of oceans, and the like.

Second, there is a markedly greater degree of pluralism in world political and economic relationships than hitherto. It was once appropriate to view the world as a bipolar system dominated by the two nuclear super powers. Now the world is shaped by the actions of a larger number of actors, including the European Community, Japan, Organization of Petroleum Exporting Countries (OPEC), the Group of 77, multinational corporations, transnational elites, and the secretariats of intergovernmental organizations. Power itself is no longer primarily military. New sources and types of political power can be found for instance in command over key resources such as food and energy and in voting coalitions in

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multilateral institutions. The use of power has become more complex in a multipolar world of shifting alliances in which different coalitions of countries face each other on different issues (Hoffman).

Third, the influence of the United States on international economic affairs has diminished. The "architecture" of the postwar international economic order was conceived by the United States, and the operation of its monetary, trade, and development subsystems was secured and nurtured by this country. Now the Bretton-Woods monetary system has been discarded; the tenets of the General Agreement on Tariffs and Trade (GATT) centered trade system (liberalism, nondiscrimination, and observance of a multilateral code of fair commercial practice) are under assault; and the developing countries have rejected the core assumptions upon which the old economic order was founded. International economic relations must be reconstructed, but the United States does not now have the hegemonic power to shape international relations according to its philosophy and preferences. Indeed, the impulse of the United States to recoil from a leadership role is strengthened by its past experience of having had to bear a disproportionate share of the costs of sustaining the old economic systems—money, trade, aid, and world food security—and by the lack of appeal it now encounters internationally for its conception of a liberal world economic order.

Fourth, international economic problems have increased in scale and complexity and the linkages between them have multiplied. This has had two important consequences. There is a growing lack of congruence between the span of problems that afflict nations and the reach of the authority and the competence of the nation state. Furthermore, interdependencies between problems have proliferated to the point where it is increasingly difficult to identify discrete problems and apply discrete solutions to them. Necessary conditions for accommodating to this aspect of international economic relations include the willingness of nations to pool their sovereignty in the attack on shared problems; agreement on the nature of solutions and modes of cooperation; and the creation of intergovernmental institutions that are structured and equipped to address present-day issues of common concern. Reality it somewhat different. Nation states are loath to surrender their autonomy. Sharp differences in the analysis of the causes of problems and in preferred solutions are the essence of international economic disharmony. Most of our postwar multilateral institutions are vertically structured, narrowly compartmentalized, and provided with mandates that are not coincident with either discrete contemporary problems or clusters of interrelated issues. Their membership spans countries at such disparate stages of economic development and with such divergent economic and political ideologies and objectives as to impede their effective functioning.

It is now commonplace to observe that functional economic interdependence is an important part of our material prosperity and that this interdependence is leading to a genuine world economy and an embryonic global polity. However, a fifth characteristic of evolving international economic relationships is a growing perception that economic interdependence has its costs as well as its benefits. For instance, while U.S. advocacy of an open world economy is partially posited on the conviction that economic interdependence fosters peaceful political relations between nations, it is quite clear that deepening economic interactions breed political frictions and resented asymmetries as well as amity. Additionally, the corollary of international interdependence is increased national vulnerability to instabilities and dislocations of external origin. Multiplication of transnational attachments erodes the authority of sovereign states by widening the area of conflict between national objectives and international obligations and by narrowing the range of national policy choices. Awareness that few countries see interdependence as a goal, and most are sensitive to its costs, can help clarify our understanding of the economic behavior of nations. Thus, the concept that states seek an optimum degree of interdependence that is normally less than the maximum is helpful in accounting for the tenacity of economically irrational protectionist policies with respect to agriculture and other sensitive industries. Furthermore, the enduring conflict between those who advocate a "market-oriented" regime for trade in farm products and those who counter with a demand for a "market-organization" approach to commodity production and trade through international agreements is really a clash between a prescription for a degree of interdependence that knows no bounds other than the uncertain dictates of market forces on

the one hand and a determination that the degree of interdependence should be limited, codified, and collectively managed on the other.

I am persuaded that these characteristics of international economic relations are to be found in the agricultural issues that currently lie between groups of states and, further, that these issues can be better understood if they are viewed against this conceptual backdrop.

Interregional Relations in Agriculture

Developed Country Relations

Discussions on the future shape of trading arrangements for temperate zone agricultural products among the advanced countries are centered in the multilateral trade negotiations currently in progress under the GATT. The matter of establishing an internationally coordinated system of nationally held grain reserves now being explored in the International Wheat Council in London will likely move to Geneva if anything of substance can be agreed on that nettlesome subject.

The trade negotiations are concerned with the traditional objective of securing freer access to international markets by further lowering tariff and nontariff trade barriers. But, in addition, the current negotiations are distinguished from the six previous GATT rounds insofar as an important part of their purpose is to strengthen the rules on fair trade by extending the articles of the agreement on such matters as national subsidy practices, access to supplies, and the use of safeguard procedures.

The United States has insisted that the negotiations must yield both freer and fairer trade conditions for her agricultural exports. The reasons are well understood. As a study by the Congressional Budget Office concluded, multilateral liberalization of trading arrangements for farm products is an optimum trade strategy for the United States in terms of the attainment of a mix of goals including enhancing domestic price and income stability, maximizing farm income, sustaining balance in external payments, and minimizing the need for government intervention in and budgetary expenditures on the agricultural sector. Improved access to foreign markets for U.S. farm products will be crucial if the recent gains in export earnings, farm incomes, and farm asset values should prove to be due to the congruence of unusual and transient events. But beyond the immediate national economic interest is a broader purpose. Agricultural trade arrangements are characterized by neomercantilist national policies, discriminatory regionalism and bilateralism, and the widespread use of national interventions that distort trade but are largely unfettered by the international rules of commercial practice embodied in the GATT. Hence, bringing this aberrant sector more surely within the framework of an open nondiscriminatory trading system governed by rules of acceptable conduct has implications for the continuing viability of the liberal international economic order that the United States has sought so long to create and sustain.

By contrast, the conviction of the member countries of the European Community (EC) is that the creation of further opportunities for expansion of trade in agricultural products must occur within the framework of a regulated international trading regime. The community has therefore proposed that international agreements be negotiated for a range of commodities, with the specific provisions of such agreements being tailored to the needs of each product. In the all-important grains sector the community has proposed that an international commodity agreement be established providing for minimum and maximum prices, implemented by the manipulation of reserve stock levels, and with reciprocal supply and purchase commitments. Japan, while exhibiting its characteristic passivity in international forums, is known also to favor trade arrangements for agricultural products that would assure her access to supplies at stable prices that might be provided by formal intergovernmental commodity agreements, multilateral stocking arrangements, and tighter rules governing the national use of export controls.

It has been customary in the United States to describe the EC's and Japan's stance on agricultural trade arrangements in both the Kennedy round and the current negotiations as camouflage for an unwillingness to expose their inefficient agricultural industries to international competition. Certainly, the political influence of the farm lobbies in Europe and Japan is real enough, and the importance of the French-German bargain and of the Common Agricultural Policy as foundation and cement respectively of the union are still central political equations in the European experiment. However, the conventional "protec-

tionist" argument does not sufficiently explain the gulf that separates the United States and other advanced countries on agricultural trade policies. The impasse on agricultural trade policy is deeply rooted in differing national economic systems and contrasting derivative views of the appropriate configurations of international economic relations.

In the United States the ascendent assumption about the national economy is that economic activity should be governed to the maximum degree possible by market mechanisms. As Shonfield has pointed out (part I), this economic philosophy carries over directly into international economic affairs. U.S. commercial diplomacy is primarily motivated by the desire to expand the area of influence of competitive markets and aimed at securing changes in the domestic economic policies and frontier measures of other governments that distort international production and trade. Additionally, the United States regards detailed commercial codes as important because they enshrine the rules of fair trade practice, provide an objective basis for determining when the rules have been transgressed, and provide a quasi-judicial process for dealing out measured penalites for infractions.

This mixture of laissez faire and legalism does not mold the behavior of other countries. Both the EC and Japan conduct their national economic affairs with a much greater degree of *dirigisme* than does the United States. More especially to our purpose, they regard their domestic agricultural policies as components of a set of integrated industrial, regional, and social policies designed to secure, at a measured pace and by government guidance, the kinds of societies they are trying to build. This philosophy and practice carries over into their international economic relations also. External relationships must be managed in such a way as not to jeopardize the attainment of broad national sectoral and regional development goals, to force an intolerable pace of industrial restructuring and social adjustment on particular groups, or to lead to an unplanned degree of dependence on external sources or excessive exposure to externally generated instabilities. Furthermore, since internal goals are constantly being redefined, the preferred style of conducting commercial relations with other countries favors pragmatic marginal adjustment through continuous negotiations and conciliation of disputes by mediation rather than the satisfaction of judicial rights embodied in binding international codes.

With such profound differences in economic philosophies and diplomatic styles, it is small wonder that exchanges between the United States, Europe, and Japan on that most sensitive of areas, agriculture, often appear to be a dialogue of the deaf.

One looks to the future with some pessimism. The time has long since passed when the United States could impose its preferences on its friends, let alone its antagonists, and the drift of the times seems to be away from both the unmanaged interdependence characteristic of open systems and the codification of interdependence in enforceable laws. Furthermore, forecasts of a rising supply price for U.S. agricultural output (Schuh 1976) and the instabilities experienced in world agriculture in the past few years have manifestly not disposed Europe and Japan to either accept a lower degree of agricultural self-sufficiency or to further expose their economies to the vicissitudes of unregulated world food markets.

One fears that the response of the United States to a failure to have its way on agricultural trade matters might be a refusal to complete the negotiations, vigorous use of the retaliatory provisions of the 1974 Trade Act, and a disinclination to cooperate in other areas of economic policy. Such a reaction would be a grievous disproportion, and perverse. Within the multinational trade negotiations there are important mutual gains to be had in liberalizing trade in manufactures and in selective strengthening of the GATT code. Beyond that, there is a host of intragroup matters requiring attention, great urgency in coordinating the developed countries' response to the demands of the third world and working out how best to conduct economic exchanges with socialist countries, and a variety of global systems problems that will only yield to cooperative solutions initiated by the advanced countries.

Meantime, Diebold's judgment seems sound when he suggests that the way agricultural trade issues between the developed countries will be resolved is not by a "catching up" to the more liberal arrangements achieved for other products "but a leap into a kind of cooperation which has not yet been established in other fields" (p. 299). However, Miriam Camps's observation that "the advanced countries are not yet ready—intellectually,

psychologically, bureaucratically—for the radical course of far more integration of their economies, far more coordination of policy, and far more collective management" (p. 43) seems *a fortiori* and ominously true of their relations on matters pertaining to agriculture.

East-West Relations

Only the most mindless optimist would suppose that military security and ideological competition will soon cease to dominate the relationship between the western democracies and the socialist countries. Nonetheless, expanding economic exchanges offer immediate and mutual economic gains, and one hopes that expanding economic interdependencies will raise the economic cost of a retreat from the process of mutual restraint we term detente.

There are a number of enduring lessons about the character of international economic relations between capitalist and centrally planned economies to be learned from the experience of selling grains to the U.S.S.R. over the past few years. I identify four.

First, the very method by which centrally planned economies conduct their economic transactions with market economies poses problems. In particular, the skillful exploitation of unequal access to information between monopsonistic procurement agencies and uncoordinated sellers can result in an asymmetrical distribution of the benefits of economic exchanges. Indeed, because central planners can consider the totality of the implications of their external transactions while externalities and secondary effects are not perceived in advance—or cannot readily be internalized—in market economies, there is perhaps an inherent propensity for socialist countries to capture a disproportionate share of the gains from foreign commerce. This view has been disputed (CIEP, p. 53), but I am not persuaded that it is without substance.

Second, permitting Russia free access to western food supplies impedes the smooth functioning of the food system in the rest of the world. In particular, so long as the Russians gear their production and consumption targets for livestock products to the peaks of their variable indigenous grain supplies, prevent rationing of consumption and resource reallocation by price variation, and make up their deficits by sporadic forays into world grain markets, they are bound to be a significant destabilizing influence. As we have witnessed, the variability of Russian import demand for grains can dislocate livestock production and consumption, destabilize prices, redistribute incomes, and complicate commercial relations between exporters and regular customers. These disturbances reach into the furthest corners of national societies and the world economy.

The U.S.S.R. is not the only source of variation in export demand. As Paalberg has noted, what distinguishes this component of world trade is that, while imposing substantial burdens on other parties by their incursions into foreign markets, the Russians have been able to avoid sharing the costs of improving the performance of the world food system—improving information, creating security and stabilization reserves, and providing balance of payment support, food aid, and agricultural development assistance to developing countries facing inflated bills for food imports. The "free-rider" feature is objectionable enough. What is worse is that the U.S.S.R.'s nonparticipation may impede the attainment of improvements that those who are willing to work together are seeking to create. For instance, it is questionable whether a durable multilateral system of grain reserves could be effectively operated—and hence negotiated—in the absence of a major trader and a prime source of the instabilities the reserves are designed to attenuate.

Finally, ad hoc accommodations to the problems caused by unstable and unpredictable export demand can force international economic relations in directions that lead away from preferred goals. Thus, while the political necessity and the economic advantages of the 1975 U.S.-U.S.S.R. agreement on grains are well understood, still and all it extended bilateralism, discrimination, and government intervention in international transactions, which are precisely the features of trade in agricultural products that U.S. commercial diplomacy has long been bent on eliminating. Indeed, the conclusion I draw is that whereas the reshaping of international economic relations between advanced countries with predominantly market economies may well be directed towards expanding the scope for market forces and reducing the influence of government interventions, this is unlikely to be feasible in dealings between groups of countries with radically different economic systems. This trade is in part politically moti-

vated, and it would appear that its conduct will require a high degree of political direction, too. This requirement in turn may necessitate changes in domestic marketing institutions and demand a multilateral code of trade rules that differ substantially from those embodied in the GATT.

North-South Relations

One of the more dramatic changes that has occurred in world economic and political relationships in the past two years is the success of the developing countries in shifting the subject of their poverty from the periphery of world affairs to the center. Their accomplishment has many causes including the use of their numerical preponderance and voting solidarity to ensure that their cause heads the agenda of all intergovernmental meetings, the success of OPEC as an examplar of their expectations and supporter of their objectives, and the growing awareness of the advanced societies that economic growth and political stability in the world is dependent upon reaching an accommodation with the two-thirds of mankind who now constitute the "down-and-ins."

The objective of the less developed countries (LDC's) is to crown their political freedom with their economic emancipation. They are seeking to achieve the latter by having international economic relations changed in ways that will place a floor under their present poverty and assure their accelerated economic development for the future.

Those who have followed the debates in the sixth and seventh special sessions of the U.N. General Assembly, the north-south dialogue in the Conference on International Economic Cooperation, and the course of the fourth United Nations Conference on Trade and Development (UNCTAD) will be aware that the concept of "a new international economic order" that the LDC's have demanded encompasses every facet of the relationship between the industrialized countries and the developing world—aid, trade, monetary arrangements, private foreign investment, control over resources, access to technology, the location of production activities, shared responsibility in decision making, and adaptations in the structure and functions of multilateral institutions. In each of these areas the LDC's are demanding not marginal tinkering but fundamental changes, the cumulative result of which would be to make their accelerated development a prime purpose of international economic relationships.

The new international economic order calls for the establishment of a comprehensive global policy for commodities (UN 1974). The so-called "integrated program for commodities" as articulated by the UNCTAD secretariat has seven principal elements (UN 1976): an expanding set of intergovernmental commodity agreements for an open-ended list of products, a common financing facility for those agreements with provisions for buffer stocks, a network of intergovernmental purchase and supply commitments, index-linking of the prices of LDC commodity exports to the prices of their imports, compensatory financial arrangements to guarantee the total value of their exports in real terms, improved conditions of access to advanced country markets, and the deliberate transfer of primary processing activities from rich to poor countries.

These measures are designed to serve two ends. The first is to improve the performance of commodity markets in economic terms by enhancing market stability and thereby the allocative function of prices and by allowing greater scope for comparative advantage to determine the location of production and processing activities. The second goal is to improve the performance of world commodity systems in political terms by effecting an international redistribution of income in favor of the poorer countries via a comprehensive, politically directed, regulatory regime governing commodity production, pricing, and trade.

These proposals constitute a truly revolutionary challenge to the existing economic order and to at least three of its central assumptions. Among these assumptions were, first, that with temporary derogations and special assistance, the LDC's would progressively adopt the predominantly market-oriented system of international exchanges employed by the advanced countries and characterized by "arms length" trading by private individuals responding to market signals. Second, trade in commodities would fit for the most part into the same kind of international economic regime as trade in manufactured products. Selective concerted interventions by governments in commodity markets might be necessary on occasion, but these were to be regarded as aberrant and transient, to be contemplated only where exceptional

economic wastes could be demonstrated, and to be implemented only when very favorable ratios between the benefits and costs of interventions were assured. A third assumption was that the international trading system was agnostic with regard to income distribution. The system's central concern was efficiency in resource use and thereby the growth of world product, not its distribution. If the international distribution of income resulting from competitive trade was politically unacceptable, presumably redistribution should be effected by direct transfers and not by the manipulation of the terms of trade and market output and shares, since such manipulations were prone to widen international inequalities in income and cause inefficiencies in world resource use.

It is apparent that the demands of the LDC's for the creation of a comprehensive, continuous, regulatory regime for commodities, in which income redistribution would be a prime goal, and in which the levels, shares and directions of production and trade, and the terms of trade would be established by political decision rather than market mechanisms, are a profoundly important development in international economic relations.

Characteristically, the main burden of making a response to these far-reaching proposals has fallen to the United States. The U.S. initial position was to maintain that the old economic order had served advanced and developing countries well, to deny that a new economic order was in the making, to stress that the primary concern must be with ensuring the growth of world output rather than with its distribution, and to emphasize that adjustments in economic relations must confer mutual benefits on both rich and poor countries to be acceptable. Subsequently, however, the United States has advanced some forty specific proposals for changes in world economic systems that would favor the developing countries and particularly the poorest among them (Kissinger 1975, 1976). All of these proposals are consistent with a liberal and a more just economic order. Many of them are coincident with the LDC's aspirations, e.g., expanded aid, easier access to western capital and technology, accelerated trade liberalization, more liberal compensatory finance provisions, and a willingness to consider on a case-by-case basis the merits of commodity arrangements with short-run stabilization objectives. Other U.S. proposals offer constructive alternatives to LDC positions. However, to the elements that the LDC's regard as central—the use of commodity policy to transfer resources to the LDC's, agreement that intergovernment commodity arrangements should be a permanent and widespread feature of world commodity systems, a prior commitment to common funding of buffer stocks, indexation of commodity prices and export receipts, and the contrived redistribution of production and processing activities—the United States has been resolute in its opposition.

How these matters will be resolved cannot be known at this time. What is certain is that the first real dialogue of mankind has now been joined and that international commodity policy is its focal point.

If we accept that relieving the present plight and improving the future prospects of poor people in poor countries is important to the kind of world our children will inherit, then the technical task is to find efficient means by which a more equitable distribution of a growing world product can be effected. There is much in this area to engage and test our profession. However, a sterner test is to decide whether our sense of belonging to a global society is sufficiently well developed to convince us that the concept of social equity should extend beyond national boundaries and exist between nations as within them.

Implications for National Policy Making

Policy making in an open economy is infinitely more complex and difficult than in one that is closed. As Tumlir has observed, the very concepts that have traditionally guided policy making—national sovereignty, national interest, and national power—are not easily defined for a country deeply involved in an interdependent world of interrelated issues. National policy makers in such a setting need to give systematic and simultaneous consideration to the domestic effects of changes in the external environment and to the external effects of changes in national policies. In a situation where "everything is related to everything else" the numbers of groups with a claim to participate in the policy formulation process multiplies and so, too, it would appear, does the scope for disputes over priorities and authority.

All this is obvious enough. The substantive point is that the fractionated existing structure of government may not be well suited to deci-

sion making and the conduct of supportive research in a situation where domestic and international issues are increasingly intertwined. Jaenke has noted that we are experiencing serious difficulties in making the adaptations in governmental structures necessitated by the perceived need to reach beyond "farm" policies to consideration of the issues of national "food" policy, i.e., a movement towards adapting sectoral policies to the wider needs of macroeconomic policy. The problems are even more complex when decision processes must find an accommodation between domestic agricultural policy requirements and goals in the wider areas of foreign trade policy, foreign economic policy, and foreign policy. The structural response to date—adding "internationalists" to the U.S Department of Agriculture and bringing people with some knowledge of agricultural matters into other branches of government; creating a mess of coordinating committees, councils, and boards; and shifting final decision authority to higher levels—may not be functionally or politically the best solution. Manning has suggested that the problems of decision making on foreign economic policy issues in the United States have already grown to the point where a radical restructuring of government has become necessary.

Implications for the Profession

International agricultural trade policy and the broader topic of international commodity policy is an area where our profession should be more heavily engaged than is presently the case. This is particularly true for a country like the United States, which is preeminent in international exchanges in farm products and which will continue to play a decisive role in determining the arrangements and rules governing global interdependence in primary commodities.

Over the years individual members of the AAEA have made many distinguished contributions to the analysis of international agricultural trade issues. But, looking at the picture in the round, it is a cause for both surprise and concern that so few agricultural economists have chosen to make a sustained commitment to the study of the international dimensions of national agricultural policy or of international commodity policy, that so much of the best work on international trade in agricultural products is being done by persons who would not claim to be agricultural economists, and that our profession at present is making such a minimal contribution to whole areas of the great contemporary debate on the future world order governing the production and exchange of primary commodities.

This is an unfortunate situation because we as a profession have so much to offer. I am not thinking only of our great tradition of addressing practical problems, of accomplishments in blending theory and empirical analysis, and of skills in systems analysis and construction of models that allow policy makers to anticipate potential future events and examine the trade-offs between policy alternatives. These are durable strengths of the profession of agricultural economics that will be required as the debate on international economic relations in agricultural products and other commodities moves from ideological confrontation to the search for practical measures of wide political acceptability. Rather, I have in mind that the course of world trade policy is beginning to move along paths we have already traveled. For instance, the subject of nontariff trade barriers, which is one of the more vibrant fields of study in international commercial policy, is only a generalization of a problem with which we in agriculture have long experience, i.e., the causal linkage between the growing involvement of national governments in industrial or sectoral policies and the adoption of neomercantilist trade policies.

Further, agriculture provides thirty years of experience—little of it encouraging but all of it illuminating—of international attempts to attenuate the adverse trade effects of domestic policies by policy harmonization, multilateral codes and agreements, and a diverse array of ad hoc cooperative measures that others now see as important instrumentalities in the collective management of interdependence (Warley). There is absolutely nothing in the perceptions and analyses of the LDC's of the nature of their commodity problems—and in the limitations of the solutions they propose—that is not instantly familiar to anyone who has spent his time working on price and marketing policies for farmers in advanced societies. Thus, our skills are required; the insights we have acquired in a domestic context are adaptable to a wider canvas; and our experimentation in international agricultural trade problem resolution contains lessons of wide applicability to international economic policy.

However, there are also some limitations on the ability of our profession to work effectively in the broad problems of agriculture in international economic relations. I mention but three items of what could be a lengthy bill of particulars.

First, we are paying a price for our overwhelming preoccupation with domestic agricultural affairs. Too many people for too long have thought about American agriculture as though it operated in a closed economy, with trade a marginal activity and even an optional extra. The result is that there does not appear to be a large number of people in the profession who are familiar with the content of the contemporary international dialogue on agricultural trade arrangements and future international commodity policy and the linkages between these matters and other aspects of international economic policy. This deficiency is magnified by the process whereby the center of gravity of national decision making on agricultural trade and commodity policy matters seems to be shifting away from the USDA, in which many of our profession are employed, and which is the principal institutional channel through which the rest of us who work outside government maintain some contact with policy priorities and policy formulation. The issues of foreign economic policy with which agricultural matters are linked and which increasingly mold national "agricultural" decisions lie entirely outside the USDA and are largely beyond our ken. Thus, the narrowness of our interests, of our setting, and of our contacts is an inheritance that bears heavily upon us.

Second, even in our role as economists qua economists, some weaknesses exist in the triad of our professional equipage of theory, methods, and data, and in work habits that impede effective functioning. Most economists have a solid in training microeconomics and quantitative analysis. If we were exposed to macroeconomics, it was likely taught primarily in terms of a closed economy. If we took a course in international trade (normally an elective), it probably did not deal with commercial policy nor was it integrated with international monetary economics or the economics of growth and development. Thus, compartmentalized curricula prepare us poorly for work on multifaceted international economic issues. I suspect that there is still truth to the ancient charge that we are "economic imperialists" in the sense that problems are defined as being primarily economic when they are not and that we are unwitting ideologues to the degree that efficiency is elevated to the status of a goal of economic activity rather an instrumental variable.

Economists are now less guilty than previously of neglecting to measure distributional effects of policy alternatives but, as Rivlin has chided us, we are convinced that we cannot say anything useful to policy makers about the welfare implications of alternative distributions of income. The assumption that the redistribution of income (even if effected by the first-best method of direct transfers) necessarily entails some sacrifice of product is probably at variance with the truth. These matters are not unimportant, for the considerations of security, stability, autonomy, equity, and status that are neglected in our received theory are the very mainsprings of national policy behavior and the core issues of international economic policy. On methods, the complaint of Krause and Nye about economists' reliance on comparative statics methodology is telling, since the scale, pace, and cost of adjustment necessitated by changes in trading arrangements are key matters for policy makers everywhere. The gaps in the data needed to adequately parameterize the external environment are so well known as to be scarcely worth remarking. But our inability to handle the realities of noncompetitive market structures, disequibria in exchange rates, and other factors that cause differences between market prices and social costs should be particularly worrisome to a profession that seems to venerate freer trade arrangements. As to work habits, one notes the paucity of genuine multidisciplinary work (although all would agree that it is desirable) in a situation where the domain of problems is rarely purely economic. Schuh has cautioned us against a professional proclivity for looking backwards in an attempt to understand the troubled present and foretell the perplexing future (1975). This is a particularly dangerous practice in studying agricultural trade and international commodity policy since in these areas of international economic relations the players, the rules and, indeed, the game itself have all changed.

Third, the institutional settings in which most economists work are not well adapted to functioning in this field. As suggested above, the structure of government is not congruent with emerging problem areas, nor ideally

suited to either decision making or the conduct of associated supportive research on linked issues. However, I am most particularly and personally aware of the constraints on the ability of agricultural economics faculty in the land grant colleges to make a contribution commensurate with our numbers and our talents. We have already been reminded by President Farrell that our research contribution is circumscribed by our being organized as a cottage industry, by too much of our work being episodic and noncumulative, by our entrepreneurial style, and by the research apprenticeship requirements of our graduate students having too large an influence on the research we choose to do, the way in which we do it, and the time taken to bring our inquiries to fruition. In our teaching function, the learning environment provided may also not be conducive to equipping students to function as policy makers, researchers, and opinion molders on the complex issues of agriculture in international economic relations. Few of the land grant colleges having agricultural economists who specialize in international agricultural trade policy also have significant numbers of faculty in related disciplines who are concerned with other aspects of international economic relations and international affairs with whom breadth and synergism in training might be achieved.

Conclusion

I have suggested in this paper that the problems of evolving international economic relations in agriculture are important and complex and further that some obstacles may exist to the successful participation of our profession in their resolution. While I am not required to provide a detailed plan for the cleansing of the Augean stable, let me end with three observations.

First, economists need to reexamine the intellectual foundations that condition the way we think about international economic relations, mold the analytical work we do and—particularly in the United States—guide national commercial diplomacy. We need to disenthral ourselves of theories that distort our perception of reality. Might it be, for instance, that the paradigm of the "objective optimality and moral neutrality of the perfectly competitive market" is less useful to us in looking at the world than the alternative of the "stabilized mixed economy" in which, as in our national economies, international economic activity is part market determined and part politically directed and which is concerned simultaneously with efficiency, stability, and equity. To illustrate I would venture that it is abundantly clear that in addressing the proposals of the LDC's on international commodity policy the three are inseparably linked, for the LDC's will not cooperate in the reform of the international economic system unless the subjects of equity and stability are addressed, and their cooperation is required if the world economy is to function effectively.

Second, our profession should be less tunnel visioned and isolationist in its work on international agricultural and commodity policy issues. Of course, the problems of trade in primary commodities have their distinctive features but for the most part issues pertaining to agriculture in international economic relations do not constitute a discrete problem set, and they are not so perceived by higher-level policy makers. We have much to gain by consciously striving to meld our work into the broader stream of international economic studies and much to offer by using our agricultural case material to illuminate the tasks, problems, and possible solutions to managing the world's deepening economic interdependence.

Finally, I deem it important that the AAEA arrange for systematic consideration to be given to alternative institutional modalities by which the contribution of agricultural economists to the study and resolution of problems of agriculture in international economic relations can be extended and enhanced in value. The "mix" of institutional arrangements through which we can function includes intergovernmental organizations, agencies of national governments, non-governmental agencies with large in-house research capabilities like the Brookings Institution, research catalysts such as the Atlantic Council in Washington and the Trade Policy Research Centre in London, universities with a commitment to international economic affairs and established multidisciplinary research and teaching programs in the area (e.g., Johns Hopkins, Chicago, Harvard, and the Fletcher School of Law and Diplomacy), research networks with multiagency involvement and central funding and direction, programs to foster professional mobility between the international organizations, government

and academe, and, not least, the honored institution of the isolated cerebrating scholar. What is the comparative advantage of each of these settings and arrangements in the conduct of what types of research? Are selective strengthening and improved coordination necessary, and if so how might these be wrought? I am not able to answer these questions. But I do have a sense that the problems of agriculture in international economic relations are so important and pressing that muddling on will not necessarily ensure that we muddle through to new policies that will avert the dangers to the world economy and to world society that lurk in the unresolved issues of international agricultural trade and commodity policy.

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Specific Sessions

The Economics of the Farm Family
(T. W. Schultz, University of Chicago, Chairman)

The Efficiency of Women as Farm Managers: Kenya

Peter R. Moock

The purpose of the study on which this paper is based is to investigate possible differences between male and female farm managers in the possession of, and means of acquiring, technical information relevant to agricultural production of maize (*Zea mays* or corn), the staple commodity of the area. Technical information is taken to mean knowledge relating to the manner in which inputs are combined. Producers are said to differ in technical efficiency when they experience systematic differences in the output produced from a given combination of inputs.[1] Allocative decision making, which has to do with the quantities of inputs used as distinct from the techniques of input use (cf. Shapiro, p. 2), is excluded from the analysis because of the absence of farm-specific price data.

The section that follows describes the geographic area, giving an explanation of the high proportion of female farm managers (relative to the ratios found in most farming communities, in Africa and elsewhere). Next, the data are described, and the model is set out in general terms. The empirical analysis follows, and finally, some conclusions.

The discussants for this session were Bruce E. Gardner of the Council of Economic Advisors and G. Edward Schuh of Purdue University.

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The collection and early analysis of the data were supported by the Rockefeller Foundation and the U.S. Agency for International Development. During this period the author was affiliated with the Institute for Development Studies, University of Nairobi, and the Center for Research on Economic Development, University of Michigan. Appreciation is owed Wallace Huffman and T. W. Schultz for many helpful insights and Victor Levine and Kenneth Shapiro for commenting on an earlier draft of the paper.

[1] In addition to systematic differences, output may be subject to random disturbances.

Women as Farm Managers in Vihiga Division

The sample (described more completely by Moock 1973) consists of 152 maize farmers in Vihiga, an administrative division of roughly 200 square miles and 300,000 people in western Kenya. Reflecting the high average population density, the typical holding consists of seven resident members and 2.5 acres.[2] The area's response to population pressure is a pattern of circular labor migration, especially by male household heads. In a random survey conducted in 1971, one-third of farm heads were found to be currently away from the family farm, engaged in or searching for work. The typical farm head has spent nearly a quarter of his total years away. The mean cumulative migration period is eleven years.

In the head's absence, farm management is relegated to another farm family member, usually the wife of the farm head. Vihiga is a notable farm community for its extent of female management. In 1971, 38% of the division's farms were managed by women. Whereas women perform a substantial portion of the physical work on farms throughout Africa, as farm managers the women of Vihiga have assumed considerably more decision-making responsibility than is generally the case.

The Model

The variable list appears in table 1. Wherever meaningful, variables are expressed as area

[2] These are median estimates derived from an earlier probability sample of farms in the division (P. Moock 1971).

Table 1. Variable List and Summary Statistics

Name	Description	Sample	Male	Female
DV-YIELD	maize output per acre (200-lb bags)	17.6 (5.7)	17.8 (6.1)	17.1 (4.9)
Physical inputs and natural factors				
1. *SCALE*	area planted in maize (acres)	1.6 (1.1)	1.8 (1.2)	1.2 (0.7)
2. *PLNTP*	plant population per acre (1,000 plants)	9.6 (2.3)	9.8 (2.3)	9.2 (2.2)
3. *LABOR*	labor input per acre (hours)	983 (339)	974 (336)	1,002 (346)
4. *CFERT*	chemical fertilizer applied per acre (lbs.)	72.6 (57.8)	79.8 (59.1)	58.5 (52.9)
5. *HYBRD*	planted any of hybrid varieties (0,1)	0.89	0.92	0.84
6. *INSEC*	used insecticide (0,1)	0.31	0.39	0.16
7. *INTER*	interplanted legume among maize (0,1)	0.57	0.51	0.67
8. *SOIL*	Applied fertilizer or left field fallow previous season (0,1)	0.36	0.43	0.24
9. *HAIL*	hailfall damage (0,1)	0.82	0.80	0.84
10. *DAMG1*	moderate damage from erosion or striga weed (0,1)	0.22	0.25	0.18
11. *DAMG2*	severe damage from erosion or striga weed (0,1)	0.09	0.10	0.08
Information proxy variables				
12. *WOMAN*	manager a woman (0,1)	0.34	0	1
13. *SCHL1*	schooling, 1 to 3 years (0,1)	0.34	0.34	0.33
14. *SCHL2*	schooling, 4 years or more (0,1)	0.34	0.43	0.16
15. *MIGR*	migration experience (years)	9.4 (10.8)	12.6 (11.2)	3.0 (5.9)
16. *AGE*	age (years)	48.8 (12.3)	51.8 (12.6)	42.9 (9.3)
17. *XTNSN*	extension contact (index)	178 (92)	191 (98)	152 (72)
18. *LOAN*	loan recipient—special extension services (0,1)	0.43	0.50	0.29

Note: The summary statistics reported are means and, in parentheses, standard deviations. The full sample consists of 152 farm observations, of which 101 are managed by men and 51 by women.

rates, a procedure that reduces collinearity among inputs and transforms X_1 (area planted) into a measure of production scale. An estimate of *YIELD* (shelled and dried maize per acre) was obtained on each farm by sampling the stand and hand harvesting the selected parts of the crop. The mean was 17.6 "bags," which translates approximately as 63 bushels, per acre. All data were recorded during the principal planting season of 1971.

As a first approximation, the production model consists of the single multiplicative equation

$$(1)\ YIELD = aX_1^{b_1} \ldots X_4^{b_4} e^{(b_5 X_5 + \ldots + b_{11} X_{11} + u)},$$

where e is the base of natural logarithms and u is a random disturbance variable. The tractable inputs, i.e., those affected by farmer decisions ($X_1, \ldots, X_8$), and three indicators of natural phenomena (X_9, X_{10}, X_{11}) are defined in table 1.

This model is incorrectly specified if knowledge can be assumed to enter into the production process. If farm managers hold different levels of technical information, and the correlations are nonzero between information and variables X_1 through X_{11}, then the estimates of b_1 through b_{11} are biased. The variables specified as the direct and indirect sources of technical information are formal schooling (X_{13} and X_{14}), experience (X_{15} and X_{16}), and extension contact (X_{17} and X_{18}).[3] In general these are factors found to affect the allocative ability of farmers.[4]

The final information proxy (X_{12}) is the focus of this paper. The right-hand columns in

[3] The appropriate algebraic specification of these variables, in the model "corrected for management bias," is by no means obvious. The equations reported in the empirical section below are the "best performing" of many that were estimated.

[4] See the midwestern U.S. studies by Huffman and by Fane and the general review by Schultz. The effect of educational factors on technical efficiency has been called the "worker effect" of education, as distinct from the "allocative effect" (Welch).

table 1 allow comparison of means (and standard deviations) for the male and female subsamples. On the average, output per acre is smaller for women (17.1) than for men (17.8), but the difference is not significant even at the 0.10 probability level.[5] The absence of a significant difference is provocative when we observe that in general the women use smaller bundles of physical inputs, especially store-purchased inputs, than their male counterparts. They use noticeably less chemical fertilizer (X_4) on average and are less likely to plant one of the hybrid seed varieties (X_5) or to use insecticide (X_6), although the mean labor input (X_3) is marginally higher on female-managed farms than on male-managed ones.

The proof of the pudding, should anyone doubt that these women were more technically efficient maize farmers than the men, is the positive coefficient on X_{12} in a regression equation (not shown) that controls for physical inputs and natural factors, i.e., in the estimation of model (1), with the term $b_{12}X_{12}$ added to the expression in parentheses. The b_{12} estimate is 0.066, suggesting that a woman obtains 6.6% more output at the mean levels of input use than does a man. This coefficient is significant at the 0.10 level.[6]

[5] Geometric means were even closer numerically—16.4 and 16.7.

[6] It falls just outside the critical region for rejection of the null hypothesis at the 0.05 level; the t-statistic is 1.63, and the critical value, 1.66.

The empirical section to follow is an analysis of the male-female efficiency difference. Two questions are explored. (*a*) Do the men and women of Vihiga benefit differentially from schooling, experience, and extension contact? (*b*) Do we observe input-specific productivity differences in the production relationships, for the male and female subsamples, when we have accounted for information sources that shift the relationship neutrally?

Empirical Analysis

The analysis begins with three estimations of a production model in which information sources ($X_{13}, \ldots, X_{18}$) are assumed to affect inputs ($X_1, \ldots, X_{11}$) neutrally. The estimated equations are given in table 2. Equation (*a*) is based on observations of male management only; equations (*b*) and (*c*), on female.[7]

Comparisons of the regression coefficients in equation (*a*) with those in equation (*b*) or (*c*) suggest several intriguing interactions between variables in the equations and the manager's sex, the criterion used in partitioning the sample. Some of these interactions are "tested" in the following equation based on the full sample of 152 farms (a prime indicates

[7] In equation (*c*), the school-extension interaction term is omitted, since the correlation between *SCHL2* and the product variable is 0.998 for women (cf. 0.881 for men).

Table 2. Regression Estimates for Examining Male-Female Differences in Technical Efficiency

Variable	(a) Male (n = 101)		(b) Female (n = 51)		(c) Female (n = 51)	
CONSTANT	0.514		−0.565		−0.585	
SCALE'	−0.078	(−1.46)	0.097	(1.47)	0.097	(1.51)
PLNTP'	0.754	(6.49)	0.462	(3.96)	0.462	(4.02)
LABOR'	0.070	(0.939)	0.153	(1.81)	0.154	(1.86)
CFERT'	0.034	(2.63)	0.045	(3.01)	0.045	(3.08)
HYBRD	0.135	(1.41)	0.113	(0.996)	0.116	(1.07)
INSEC	0.039	(0.486)	0.278	(2.55)	0.277	(2.59)
INTER	0.102	(1.68)	0.053	(0.559)	0.050	(0.555)
SOIL	0.097	(1.88)	0.128	(1.61)	0.128	(1.64)
HAIL	−0.060	(−0.878)	−0.310	(−2.95)	−0.310	(−3.01)
DAMG1	−0.180	(−3.25)	−0.184	(−2.29)	−0.186	(−2.43)
DAMG2	−0.339	(−4.31)	−0.094	(−0.871)	−0.094	(−0.890)
SCHL1	−0.119	(−1.81)	0.187	(2.08)	0.189	(2.13)
SCHL2	0.177	(1.37)	0.382	(0.272)	0.209	(2.04)
MIGR'	0.0031	(0.329)	−0.017	(−1.64)	−0.017	(−1.66)
AGE'	−0.071	(−0.702)	0.325	(1.74)	0.330	(1.85)
XTNSN'	0.029	(2.52)	−0.0072	(−0.406)	−0.0075	(−0.434)
LOAN	0.072	(0.721)	−0.440	(−3.38)	−0.444	(−3.58)
(*SCHL2*) (*XTNSN'*)	−0.033	(−1.45)	−0.034	(−0.122)		
R^2	0.853		0.889		0.889	

Note: Dependent variable is log of *YIELD*. Regression coefficients are given first, followed by t-statistics in parentheses. A prime indicates that the variable is entered in log form.

the variable is measured in logarithms; numbers in parentheses are t-statistics):[8]

$$
\begin{aligned}
(2)\quad YIELD' = {} & 0.461 - \underset{(-1.25)}{0.054(SCALE')} + \underset{(1.29)}{0.090(WOMAN)(SCALE')} \\
& + \underset{(7.10)}{0.733(PLNTP')} - \underset{(-1.85)}{0.280(WOMAN)(PLNTP')} \\
& + \underset{(0.998)}{0.056(LABOR')} + \underset{(2.15)}{0.108(WOMAN)(LABOR')} \\
& + \underset{(4.17)}{0.039(CFERT')} + \underset{(1.38)}{0.100(HYBRD)} \\
& + \underset{(1.58)}{0.098(INSEC)} + \underset{(1.90)}{0.091(INTER)} \\
& + \underset{(2.17)}{0.087(SOIL)} - \underset{(-2.16)}{0.121(HAIL)} \\
& - \underset{(-4.25)}{0.187(DAMG1)} - \underset{(-4.70)}{0.299(DAMG2)} \\
& - \underset{(-1.95)}{0.112(SCHL1)} + \underset{(1.98)}{0.167(WOMAN)(SCHL1)} \\
& + \underset{(2.02)}{0.215(SCHL2)} + \underset{(2.82)}{0.030(XTNSN')} \\
& - \underset{(-1.92)}{0.038(SCHL2)(XTNSN')} - \underset{(-1.50)}{0.028(WOMAN)(XTNSN')} \\
& - \underset{(-0.784)}{0.061(LOAN)};\ R^2 = 0.705.
\end{aligned}
$$

Whereas a little schooling (one to three years) is associated with higher yields for the women in our sample, this does not apply to the males. In the men's case the relationship appears to be an inverse one between some schooling and technical efficiency. On the other hand, those who have attained four or more years in the formal system, men and women alike, do obtain more output per unit of input on average than do farmers who have not been to school.[9]

Equations (*b*) and (*c*) in table 2 suggest that migration experience (years away from home) is a detriment to a woman's technical skills as a farmer, though the coefficients on *MIGR'* are not significant in two-tailed tests.[10] There is no indication in equation (*a*) that prior absence affects a male manager's skills in one direction or the other. A reasonable interpretation of this is that men, when they "go to town," typically leave the family at home and, through visits and correspondence, manage to keep informed about the farm. Women who migrate are usually accompanied by husband and children. With no immediate family left on the farm, they do not learn of new techniques in farming. The equations in table 2 indicate that the manager's age correlates positively with technical efficiency, as predicated, but only for women.[11] The correlation does not exist for men. These interactions, while interesting, are weak and do not hold up in any equation based on the full sample. Thus, the experience variables are left out of equation (2).

Equation (2) indicates that exposure to the Ministry of Agriculture is associated with greater technical efficiency, provided the farmer is male and not too well educated. The elasticity with respect to *XTNSN* is 0.03 for males with three years or less of schooling, but the effect vanishes for men with four or more years attainment and is not present in the case of women.[12] All else being equal, the possession of a government loan for the purchase of maize inputs (seed, fertilizer, and insecticide) is associated, in table 2, with smaller yields for female managers—a paradox since loan recipients were to be given close supervision.

In table 2 there are some apparent differences between the male and female subsamples in the size of the effects of various inputs on the output measure. Two of the differences are significant, and one nearly so; these appear in equation (2). The women seem to have made better use of labor in the production of maize than the men; they benefited less from

[8] The dummy variable *WOMAN* does not appear by itself in equation (2). When added, its coefficient, while positive, is not significant, nor is the coefficient on the female-labor product variable (the two are correlated at 0.997).

[9] Taking the partial derivative of equation (2) with respect to *SCHL2* and using the mean value of *XTNSN'* (4.348) yields $\partial YIELD'/\partial SCHL2 = 0.177 - 0.033(4.348) = 0.034$. Judging from table 2, this estimate probably understates the effect of *SCHL2* for women, though not for men.

[10] The sign of b_{11} could not be predicted a priori, since the content of migration experience is nowhere indicated in the data set although this dimension is known to vary substantially across farm managers.

[11] Age (migration time held constant) serves as a measure of experience on the family farm and, at least as such, should be a direct indicator of production knowledge.

[12] The index *XTNSN* is based on five binary indicators of extension contact: "Since this time last year, have you . . ." (*a*) been to consult a Ministry of Agriculture (MOA) instructor? (*b*) been visited by a MOA instructor? (*c*) attended a MOA crop demonstration? (*d*) attended a MOA animal demonstration? (*e*) attended a course at a Farm Training Center? The procedure used to weight indicators is described elsewhere (P. Moock 1973, pp. 160–65).

the density of the maize stand (*PLNTP*). The returns to production scale appear positive for women and negative for men, although in neither case is the effect significantly different from zero. *Ex post* explanations of these differences are highly speculative and are not attempted in this paper.

Conclusions

This paper has looked at sex-linked differences in production knowledge on the part of small-scale maize farmers in an area of Kenya. If such differences do exist, they are likely to be quite local and transitory. The hypotheses tested here relating to male-female differences in technical efficiency are nondirectional ones. To conclude, the findings are summarized and some interpretations are advanced.

First, the impact of schooling on output, other factors remaining the same, is greater for the women than for the men. The men who had been to school for just a few years performed worse on the efficiency criterion than those who had never been to school. The author concludes that literacy and numeracy, skills emphasized in primary education, are applicable to the acquisition of information used in small-scale farming, as evidenced by the schooling-output relationship for women.

The men who advance further in school are more likely to participate in the search for off-farm employment. Generally, it is only the more able individuals who find and keep jobs. Thus, men found managing farms despite educational credentials may have lower than average ability. This selection mechanism biases the male subsample with respect to the overall ability distribution but probably does not apply to the women, who are seldom expected to find work off the farm. It may also not apply to men with four or more years of school. These very educated men often find off-farm employment locally (e.g., as shopkeepers or primary teachers), which allows them to look after their farms at the same time (J. Moock).

Another striking finding has to do with the impact of the extension services on farming. The women seem not to benefit, as the men do, from extension contact, perhaps due to the marked male orientation of the services as provided by Kenya's Ministry of Agriculture. The staff consists almost entirely of men, the few exceptions dealing exclusively with "home economics" (nutrition and health). Moreover, much of the ministry's agricultural instruction takes place at the chiefs' *barazas* (regularly held meetings), attendance at which is seen particularly as the prerogative of male elders. Although women do attend, their participation is limited. The ministry makes scant use for instructional purposes of the churches, in which women play a much more active role.

Some farmers in the sample received maize input loans in 1971, granted through the ministry in conjunction with Kenya's Agricultural Finance Corporation. As credit recipients they qualified for special extension services. The loans were extended that year as part of an experimental rural development program. In planning the program, the government staff was divided, a vocal minority arguing against the inclusion of women, whose farming skills and whose obligation to repay debts (under existing laws) were considered dubious. Although this view did not prevail, and some women received credit, this skepticism may have exacted its toll, since the women with loans got smaller yields on average than did the women without them.

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The Value of the Productive Time of Farm Wives: Iowa, North Carolina, and Oklahoma

Wallace E. Huffman

Farm wives allocate their time outside of the household to two work activities, farm and off-farm work. Although few studies have attempted to determine the value of the time of farm wives devoted to farm production, the value of their time is important for understanding the level and fluctuation of farm household income and the changing time allocation of farm wives.

The study on which this paper is based focuses on assessing the value of time spent by U.S. farm wives at farm work. The data on wives' farm work were derived from the 1964 *Census of Agriculture* (U.S. Dep. Commerce 1967, 1968). These data have deficiencies, but until surveys are revised to better measure the working time of farm wives, these and similar data are the best available. The results of this study show that farm work by farm wives contributes significantly to farm output and that the marginal product of their time at farm work compares favorably with their nonfarm wage.

The paper is organized as follows. First, participation of farm wives in farm work is discussed. Next, the empirical analysis describes the data, empirical model, and the results. The last section presents the implications.

Participation of Farm Wives in Farm Work

Much of U.S. agriculture continues to be organized around the institutional structure of the family farm, and husband-wife families are the predominant family type. Modern economic growth and the accompanying adjustments have, however, brought significant changes in farms and farm families. During the past fifty years, growth in the demand for nonagricultural products relative to agricultural products and concommitant adoption of labor-saving agricultural technology have created economic incentives for large numbers of people to leave farming; those farms that remain have become larger and more mechanized.

In both farm and nonfarm households birth rates have fallen during the past two decades, and households have purchased many new durable goods, some of which are labor saving. Both factors have contributed to a reduction in the demand for wives' household time, thereby releasing additional time for work outside of the household and/or for "leisure" time. Furthermore, evidence shows a rising participation of farm wives in work outside of the household. This pattern is similar to the rising labor force participation of nonfarm wives (U.S. Dep. Labor).

Farm wives are indeed an important source of labor on farms. But the magnitude and change in this labor input is difficult to assess because of a paucity of data and deficiencies in data that are collected. In the *Census of Agriculture,* except for 1964, neither the number of wives working on farms nor their hours (or days) of farm work are collected. In other data, many working farm wives are not counted as being employed in agriculture. The primary reason is that most wives working on family farms are classified in the occupation of unpaid family workers. The Bureau of Labor Statistics (BLS) (U.S. Dep. Labor 1960, 1972), Bureau of the Census (U.S. Dep. Commerce 1972), and U.S. Department of Agriculture (1965) fail to count as being employed the unpaid family workers who work less than 15 hours during the survey

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week. A secondary reason is the timing of surveys, given the seasonality of farm work. For example, the BLS labor force participation rate survey is taken in mid-March, clearly a slack time on most farms. A third reason is that multiple job holders are classified by the BLS and the Bureau of the Census as working in the industry where the largest number of hours are worked. Thus, farm wives with both farm and nonfarm work may be counted as working only in the nonfarm sector.

The special farm labor report of the 1964 *Census of Agriculture* does provide comprehensive national estimates of farm work by farm wives (U.S. Dep. Commerce 1968, tables 3 and 4). This report uses a broad definition of farm work and contains data on hours of farm work for fifty-two survey weeks of a year for all farm household members.[1] These data show an annual average participation rate in farm work by farm wives of 42.8%, varying from 37.1% in January to 48% in June (see table 1).[2] Wives reporting farm work devoted an annual average of 19.9 hours to it per week, varying from 17 hours in January and March to 22.3 hours in July. (Farm operators, who reported farm work, worked an annual average of 41 hours per week.) Thus, although these data show a relatively high rate of participation by farm wives in farm work, the average number of hours of work per week is significant but not large.

Data on the participation of farm wives in farm work for other years are unavailable. Thus, a trend cannot be established. But one could hypothesize that the long-term trend in wives' participation in farm work has been upward, although not as rapid as the labor force participation rate for all women, with cycles about the trend caused by disturbances—major wars, business cycles, and cycles in farm profits—in the farm and nonfarm labor markets. The increasing mechanization of agriculture—especially size, versatility, and power accessories of tractors—and mechanization of livestock feeding have made physical strength less important for many farming activities. Tractors with radios and air-conditioned cabs have improved the quality of working conditions, especially in crop production. The steadily falling number of hired workers and teenage children in farm households leaves only wives on many farms to provide human assistance with two-person farming activities. The generally increasing size of farm businesses and the dynamic economic environment facing farmers have increased the expected return from accurate and complete business records, and farm wives do much of the farm-business record keeping.[3] Also, as more farm husbands take full- or part-time off-farm jobs (U.S. Dep. Commerce 1967, pp. 514–18; 1973, p. 178), wives are left to supervise and do the farming.

We cannot forget that the off-farm labor force participation rate of farm wives has risen significantly from 16% in March 1959 to 26% in March 1971 (U.S. Dep. Labor). Thus, increasing hours of off-farm work may account for all the increase in hours of nonhousehold work by farm wives.

Table 1. Labor Force Participation by Farm Wives on Family Farm

Month	Rate[a] (%)	Hours/Week for Wives Working
April 1965	41.2	18.7
May	46.9	20.1
June	48.0	21.9
July	47.4	22.3
August	45.7	21.9
September	44.2	20.6
October	43.9	21.0
November	42.1	20.2
December	38.4	17.4
January 1966	37.1	17.1
February	36.8	17.2
March	37.8	17.1
Average, annual	42.8	19.9

Source: U.S. Dep. Commerce 1968, tables 3 and 4.
[a] See footnote 2.

The Empirical Analysis

The productive value of farm wives' time in farm work is to be assessed by estimating an aggregate production function. The data, empirical specification of the model, and the empirical results are presented and discussed.

[1] Farm work is defined as farm work or chores, work in fields, milking, care and feeding of livestock and poultry, care and repair of equipment and buildings, keeping farm records, and planning and supervising farm work.

[2] The labor force participation rate is calculated as the ratio of the number of farm wives working to the number of farm operators working during the survey week for farm operators and wives who worked on their own farm and were not paid a wage. This is not a conventional definition of labor force participation, but it seems appropriate here.

[3] This conclusion is from a report prepared for a different purpose (Schreier).

The Data

The observations are per farm county averages for all 276 Iowa, North Carolina, and Oklahoma counties. These observations were chosen because in these states agriculture continues to be an important industry, the family farm continues to be the predominant institutional structure, and the states represent different geographic regions of the United States—Midwest, Southwest, and Southeast—that have different on-farm and off-farm work opportunities for farm wives.

County tables from the 1964 *Census of Agriculture* are the primary data (U.S. Dep. Commerce 1967, 1968). Farm outputs and inputs are measured as flows. Output by final product type is gross product and is measured as value of sales, home consumption, rental value of farm dwellings, government farm program payments, and net increase in farm inventories. The inputs of husband, wife, and hired labor are derived from flow data on actual numbers of days worked on farms.[4] Man-(woman-) days of farm work per year are derived from adjusted weekly hours of farm work by farm operators (nonoperator household members) and from annual expenditures on hired labor.[5] Education of farm husbands (wives) is an index derived as an income weighted average of the number of farm operators (wives of farm operators) in seven different schooling completion classes.

The land-and-building input is measured as the rental on the current value of farm land and buildings; the fertilizer and seed input is measured as price weighted primary plant nutrients plus expenditures on seed. Machinery services are the rental on an inventory of a selected group of machines on farms in 1964 plus expenditures on petroleum products. The livestock input is measured as the rental on the inventory of breeding stock plus expenditures on purchased livestock and feed. An agricultural extension input is derived from unpublished Federal Extension Service data for 1960 as the annual average number of one-tenth man-days spent on crop and livestock activities by agricultural extension agents (USDA 1961).

The arithmetic mean value of annual days worked by Iowa wives of 105 is much larger than for wives of North Carolina (40) and Oklahoma (64).

The Empirical Specification

The empirical specification of the production function is

$$(1)\quad \ln Y_{ij} = \alpha_{IA}D_1 + \alpha_{NC}D_2 + \alpha_{OK}D_3 + \sum_{l=1}^{k=3} \alpha_l \ln X_{ijl} + \sum_{l=1}^{k=3} \beta_l \rho \ln X_{ijl} + \mu_{ij},$$

where ρ is the share of final livestock output in total output, $E\mu_{ij}^2 = \sigma_i^2$, and D_i is a 1-0 state dummy variable. The specification permits the input-output relationship to vary by product mix of output and the intercept and variance of the disturbance of the function to differ across states. The appropriate estimation procedure for equation (1) is weighted (generalized) least squares. (See Huffman 1976b for more detail.)

The Empirical Results

The results from fitting equation (1) to the 276 observations of per farm county averages are reported in table 2. All the estimated α's are positive and significantly different from zero, except for the coefficient of fertilizer and seed input. The input coefficients, $\alpha_l + \rho\beta_l$, (and partial elasticity of output with respect to X_l) for wife labor and three of the other inputs differ significantly by product mix of output. For wife labor, the input coefficient declines as ρ increases. By assuming that variable factors are paid proportionally to their marginal product and total payments just exhaust output, the estimate implies that the factor cost share of wife labor is largest on crop farms and declines as the relative importance of livestock output increases. The results also yield implications on factor ratios. As ρ increases, the cost-minimizing ratio of wife to hired labor increases, but the ratios of wife labor to other inputs decline.[6]

The three right-hand columns of table 2 provide estimates of an agricultural produc-

[4] Estimates of the partial elasticity of substitution between these labor inputs are not particularly large (Huffman 1976b).

[5] The variables are defined the same as in Huffman (1976b), except for land-and-buildings input and the grouping of fertilizer, seed, and livestock into two input classes. See Huffman for more details (1976a).

[6] Setting marginal rate of substitution of X_i for X_j in production and exchange equal, the sign of $\frac{\partial(X_i/X_j)}{\partial\rho}$ is determined by the sign of $\beta_i\alpha_j - \alpha_i\beta_j$.

Table 2. Estimate of an Aggregate Agricultural Production Function for Iowa, North Carolina, and Oklahoma, 1964

Input	Regression Coefficient (t-ratios)	Implied Coefficients (t-ratios)		
		$\bar{\rho}_{IA} = 0.66$	$\bar{\rho}_{NC} = 0.33$	$\bar{\rho}_{OK} = 0.53$
Land and buildings[a]	0.073	0.073	0.073	0.073
	(2.28)	(2.28)	(2.28)	(2.28)
Fertilizer and seeds	0.022	0.022	0.022	0.022
	(1.02)	(1.02)	(1.02)	(1.02)
Machinery	0.441	0.441	0.441	0.441
	(9.73)	(9.73)	(9.73)	(9.73)
Livestock	0.132	0.488	0.310	0.418
	(5.11)	(23.02)	(15.42)	(21.11)
Hired labor	0.214	0.045	0.130	0.078
	(7.52)	(2.23)	(7.30)	(4.48)
Husband man-days × husband education	0.419	0.313	0.366	0.334
	(8.67)	(6.36)	(7.55)	(6.83)
Wife woman-days × wife education	0.196	0.090	0.143	0.111
	(2.92)	(1.36)	(2.15)	(1.68)
Extension	0.015	0.015	0.015	0.015
	(3.16)	(3.16)	(3.16)	(3.16)
ρ × livestock	0.539			
	(14.40)			
ρ × hired labor	−0.256			
	(−4.94)			
ρ × husband man-days × husband education	−0.161			
	(−11.15)			
ρ × wife woman-days × wife education	−0.161			
	(−11.15)			
D_1	−4.462	−4.462		
	(−4.11)			
D_2	−4.226		−4.226	
	(−4.11)			
D_3	−4.429			−4.429
	(−4.19)			
R^2	0.999			
$\hat{h}_j$		1.472	1.485	1.477
(s.e.)		(0.075)	(0.076)	(0.075)
$\hat{\sigma}_i^2$		0.0045	0.0186	0.0080
$\hat{\hat{\sigma}}_i^2$		0.0037	0.0217	0.0075

Note: These weighted least squares estimates of the parameters of the production function are based on averages for 276 counties of Iowa, North Carolina, and Oklahoma. β's that had small t-values when all coefficients were estimated were constrained to being zero, and the two-stage weighted least squares estimation procedure was repeated. Weights are the $\hat{\sigma}_i^2$'s.

[a] Variables are in natural logarithms, except for extension and ρ, which are in level form.

tion function for Iowa, North Carolina, and Oklahoma, respectively. The coefficients of each function are evaluated at the mean value of ρ for each state subsample. The estimates of the scale parameter (h_j) for the functions are significantly larger than unity. Thus, for all three states, the results imply economies of scale in agricultural production. The scale parameter is largest for North Carolina and smallest for Iowa, but none of the differences is statistically significant. Differences in the intercepts for the three functions do not imply efficiency differences; they are largely the result of procedures used in deriving the variables.

Implications

A major postwar change in the U.S. economy has been the rising labor force participation rate of married women. An immediate consequence is larger household incomes and larger quantities of goods and services produced and consumed. For farm households, increased hours of work by wives requires allocative decisions on working time. Additional hours could be used to increase the total quantity of available farm resources to permit a substitution of wife for hired labor and other inputs. Alternatively, additional hours of work could be devoted to nonfarm wage work. A

Table 3. Mean Marginal Products for Representative Farms, 1964

Variables	Geometric Means (Subsamples)			Marginal Products[a] (Standard Errors)		
	Iowa	N. Carolina	Oklahoma	Iowa	N. Carolina	Oklahoma
Estimate of mean output (1964 \$/year)	17,038.9	6,621.5	6,991.0			
Land and buildings (1964 \$/year)	5,045.1	907.6	1,320.4	0.247	0.533	0.387
				(0.12)	(0.24)	(0.17)
Fertilizer and seeds (1964 \$/year)	710.9	414.6	289.6	0.527	0.351	0.531
				(0.51)	(0.34)	(0.56)
Machinery (1964 \$/year)	2,488.5	1,075.0	1,370.0	3.020	2.716	2.250
				(0.31)	(0.28)	(0.23)
Livestock (1964 \$/year)	5,799.7	975.4	2,527.1	1.434	2.104	1.156
				(0.06)	(0.14)	(0.05)
Labor						
Hired (man-days/year)	32.0	70.6	38.0	23.96	12.19	14.35
				(10.76)	(1.67)	(3.20)
				[10.90][b]	[6.60]	[9.10]
Husband (man-days/year)	273.7	140.4	153.1	19.49	17.26	15.25
				(3.06)	(2.29)	(2.23)
				[16.71]	[13.67]	[15.96]
Wife (woman-days/year)	104.7	39.9	63.8	14.65	23.73	12.16
				(10.76)	(11.04)	(7.25)
				[13.84]	[11.48]	[12.84]
Education (1959 \$/year)						
Husband	5,594.8	5,104.0	5,648.6	0.953	0.475	0.413
				(0.15)	(0.06)	(0.11)
Wife	3,043.4	2,775.7	2,994.0	0.504	0.341	0.259
				(0.37)	(0.16)	(0.16)
Extension[c] (0.1 days/year)	0.64	3.18	1.69	255.58	99.32	104.87
				(82.77)	(32.17)	(33.96)
$\hat{h}_j$				1.472	1.485	1.477

[a] Marginal products are calculated from the minimum variance unbiased estimate of conditional mean output (Goldberger) using geometric means of inputs and $\hat{\sigma}_j$'s (table 2). Standard errors are calculated using the equation for exact variance of products (Goodman).
[b] The numbers in brackets are cost per day in 1964 of respective type of labor. For hired labor the cost is the state average daily wage rate (USDA 1965), and for husbands and wives, the cost is the geometric average daily wage rate for off-farm work by farm husbands and wives, respectively (U.S. Dep. Commerce 1967).
[c] Arithmetic mean for input.

comparison of the implied marginal products from this study of wives' time, adjusted for economies of scale of about 1.5, with the nonfarm wage rate of farm wives (table 3) shows that farm family incomes in Iowa and Oklahoma (North Carolina) would have been larger in 1964 if additional hours of wives' time had been allocated to nonfarm work (farm work).[7] None of the differences between marginal products and wage rates are statistically significant. One does puzzle at the reasons for the large differences across the three states in the marginal product of wives' time.

Even if mean changes in family income are the same for additional hours of farm and nonfarm work of wives, other effects will differ. The return from added farm work is more difficult to identify than regular wage payments for nonfarm work because it is obtained as net farm income (a residual), which is a return to several "unpaid" factors and is subject to large annual variation due to abnormal weather conditions and output prices. Because variation in nonfarm wage income and net farm income are not highly correlated, additional hours of nonfarm work by wives opposed to farm work reduce the variance in farm household income. If households face significant credit rationing or are risk averse to variation of income, they may prefer added nonfarm work for wives even when the expected nonfarm wage is less than the expected marginal product of wife's time from farm work.

Although the labor force participation of wives is increasing, wives continue to allocate large numbers of hours to work in the house-

[7] The off-farm wage rate (table 3) is the opportunity cost of wife's time only when she works at nonfarm jobs and when hours of off-farm work are flexible. If the wife does not work at off-farm work, the opportunity cost of time is the value of the marginal household utility of her time in household activities.

hold, complicating decisions on skill acquisition through formal training. Wives who work both outside and inside the household are "multiple" job holders and should invest in skills that raise the productivity of their time in both activities. For example, when outside work is nonfarm work, skills for nursing and elementary school teaching are useful in both the household and market. When outside work is farm work, overlapping skills seem less likely.

The results of this study do permit a comparison between the marginal product of education of farm wives at farm and nonfarm work. The average education index gives the income that the average education mix of wives in a state would generate in nonfarm labor income in 1959. If nonfarm wage rates rose 10% between 1959 and 1964, then the marginal product of education in 1964 should be about 1.1. The relatively small marginal products of wives' education suggest that investment in wives' formal education raises their productivity more rapidly at nonfarm than at farm work. However, for wives with low levels of education, the effect of expanded coverage of minimum wage legislation probably has increased their quantity of farm work. Being self-employed or working as an "unpaid" family worker are ways of circumventing the unemployment effects of minimum wage legislation. But as education levels of farm wives rise, this effect should diminish.

In conclusion, it is clear that farm wives participate in and are productive at farm work. However, I challenge others to obtain new and better data and to attempt to determine the value of the productive time of farm wives so that we may gain a better understanding of the level and fluctuation of farm household income and allocation of time of farm wives.

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The Demand of Farm Families for the Quantity and Quality of Schooling for Their Children in the United States

Mark R. Rosenzweig

In recent years economists have become increasingly interested in the roles of education in the agricultural sector. The pioneering studies by Gisser and Welch on the relationship between education, farm employment, and agricultural production and the vast emerging literature on the importance of education in a dynamic context, summarized by Schultz, are notable examples. Economists have also been studying the determination of the level of human capital acquired by individuals as well as the returns to various dimensions of schooling that go beyond the most commonly utilized measure—years of school completed. These latter studies, however, have primarily focused on the nonagricultural population. In this paper an attempt is made to formulate and test on U.S. data pertaining to the early 1960s a model of the farm family that integrates the schooling of farm children among the set of household production and consumption decisions and explicitly accommodates the roles of education in agricultural production while distinguishing between the quantity and quality of schooling. This latter distinction is particularly important in the farm population.

Theoretical Framework

Two principal characteristics of farm families differentiating them from their nonfarm counterparts are that school-age farm children can readily participate in farm production and contribute to family income and that the level of schooling a child acquires directly influences the farm family's income to the extent that schooling enhances farm productivity. Moreover, schooling plays an important role in the migration of children from the family farm. In describing the demand for the schooling of children by farm parents in an optimizing framework, three functions are central to the analysis. (A formal two-period version of this model is found in Rosenzweig 1977b.) The farm family is assumed to maximize an intertemporal utility function whose arguments are the per period flow of services from purchased commodities and the accumulated human capital of the farm children (child quality).

Parents can augment child quality in each period according to a schooling production function, which describes the relationships between gross investment in child human capital per period and the schooling inputs—the time children spend in school (measured in years, days, hours, etc.)—school quantity—and the total amount of school-related goods and services purchased in the market (teachers, books, and other classroom materials)—school quality. For simplicity it is assumed that the farm family is in the stage of its life cycle such that the total number of children, hence the maximum amount of child time available for schooling each period, is predetermined and all child investment occurs in school. Thus, the possible interactions between decisions concerning the quantity of children and child schooling (quality) is excluded from the analysis as well as the important roles parents play in the preschool years, as documented by Leibowitz and others. (For an analysis of child-quantity decisions by farm families, see Rosenzweig 1977a.) To capture the latter in part, assume that the educational level of the farm parents enhances the productivity of child time in school as well as the productivity of school-oriented expenditures.

The third function describes the intertem-

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poral production possibilities of the farm family, assumed to live on a farm of predetermined economic capacity as measured by the value of the farm assets owned by the farmer. Within the vector of farm production, inputs are assumed to be the time ("raw") farm children devote to farm production in the schooling periods and the services of the human capital of "skilled" farm children in the postschool periods. Child human capital is thus a production as well as a consumption commodity. Schooling investment, however, increases earnings capacities in both farming and other activities, thus enhancing the prospect of farm children obtaining nonfarm jobs. The willingness of farm parents to finance investment in general skills may in part be explained by the declining nature of farming as an occupation; farm parents anticipate that many of their children have to leave agriculture and see schooling as a means of increasing their welfare in the nonfarm sector.

The optimal levels of school quantity and quality are determined where marginal costs equal marginal returns. The returns to, in contrast to the marginal costs of, both schooling inputs are similar: the marginal product of the input in the schooling function multiplied by the sum of the marginal pecuniary and nonpecuniary benefits from schooling, the values of marginal product and marginal utility of child human capital. The marginal cost of school quality is the market-determined price of the school quality inputs.

The cost of an additional unit of the quantity of schooling, the transfer of a unit of child time from farm to human capital production in school, is equal to the marginal value product of "raw" child labor in agricultural production. Thus, the shadow price of the quantity of schooling in agriculture is dependent upon the allocation of production and consumption inputs by the farm family, while the cost of a unit of school quality is not.

To illustrate the importance of the differential shadow prices of school quantity and quality in agriculture as well as the consumption and production aspects of education, consider the influence of an increment in the economic capacity of the farm (value) on the demand for school quantity and quality. Increases in farm value unambiguously raise the demand for school quality as long as child quality is a noninferior consumption commodity. An increase in farm capacity leads to a higher demand for schooling and for the quality input because it raises both farm income and the marginal value product of "skilled" farm children.

The relationship between farm value and school quantity is not unambiguous. While the effects of an increase in farm productive capacity on the returns from the school quantity and quality inputs are similar, unlike in the former case the shadow price of school quantity also rises as increases in farm value raise the marginal value product of "raw" labor and the opportunity cost of time in school. Farms with greater potential productivity demand higher levels of schooling but also tend to substitute school quality for quantity. The (positive) effect of farm value on school quality is stronger than its effect on school quantity. If the substitutability between productive assets and unskilled child labor is high, a negative relationship between the quantity of schooling and farm value may be observed.

A general implication of the analytical framework is that parameters related to agricultural production, such as the cost of production inputs, the quality of land, and the available technology, differentially influence the demand for the quantity and quality of schooling in agricultural populations. In addition if mature children participate in the allocative decisions on the farm, the rate of technological change would increase the demand for child schooling if the farm parents perceive the usefulness of education in the adoption and use of new technologies. Farmers may also be sensitive to variables affecting the off-farm employment prospects of their offspring, since these variables influence the expected pecuniary returns from school investment as well as the welfare of their migrant children.

Empirical Analysis

The Data

Demand equations for school quantity and quality relating the level of the two school inputs to the exogenous production and consumption variables discussed can be derived from the theoretical framework. To estimate these equations, U.S. state cross-sectional data are utilized, extracted mainly from 1960 census sources. (A detailed description of the variables and their sources are contained in Rosenzweig 1973, 1977b.) The two dependent

variables representing, respectively, the quantity and quality of schooling are the natural logarithm of the nonenrollment rate of rural farm teenagers aged 15 to 18 (see Edwards for a rationale for this form of the enrollment variable) and instructional expenditures per enrolled child in rural school districts and counties.

While micro data may be more appropriate for testing models of household behavior, data availability preclude the use of less aggregative variables. However, because expenditures on education are implemented for the most part by governmental units in the United States, the assumption of the theoretical analysis that the levels of school quantity and quality are jointly determined at the household level may be unrealistic, as all households, including those in other geographical areas and those without school-age children, participate collectively in the budgetary process. In considering the aggregate demand for school quantity and quality, the population demographic composition and fiscal structure must therefore be taken into account as well as the possibility that the two aggregate schooling variables may interact. Accordingly, both ordinary least squares and two-stage least squares estimating procedures are utilized.[1]

Of the independent variables, listed in table 1, those central to the analysis are farm value, representing potential agricultural income, total nonfarm income, and a measure of total factor productivity change constructed from the indices developed by Evenson and Landau and used as a proxy for the degree of disequilibrium. The wage rate of agricultural labor is used to represent the price of one farm input that varies significantly in the cross section. The educational levels of adult farm males and females are included to capture schooling preferences and child schooling adult schooling interactions. The unemployment rate of 20- to 25-year-old urban whites represents the set of possible variables measuring nonfarm employment prospects for farm children.

The state minimum lawful school-leaving age, the percentage of nonwhite farm operators, the ratio of the school-age (5 to 18) to total population, the proportion of the school population of high school age, and the proportion of the local governmental budgets financed by superior governmental agencies are also added to the data set as control variables. The latter three take into account the public expenditure aspect of the school quality proxy.

Table 1. Variable Means and Standard Deviations: U.S. Rural Farm Population, 1960

Variable	Mean	Standard Deviation
School enrollment rate of farm population aged 15–18	0.802	0.076
Per pupil instructional expenditures in rural schools	168.2	44.07
Farm value	23,955	16,650
Nonfarm income (1964)	907.0	330.4
Percentage (+100) total factor productivity change (1950–59)	113.2	9.45
Hourly agricultural wage (annual average 1954–59)	0.73	0.17
Median years of schooling of farm males aged 35–44	10.0	1.82
Median years of schooling of farm females aged 35–44	11.0	1.49
Urban unemployment rate of white males aged 20–25	5.95	1.36
Percentage of farm operators nonwhite aged 35–44	5.33	11.3
Minimum lawful school-leaving age	15.6	3.45
Percentage of 5–18 farm population aged 15–18	31.1	2.80
Proportion of total farm population aged 5–18	0.263	0.022
Percentage of local school budget locally financed	55.4	19.2

Note: n = 44 states; Alaska, Hawaii, Connecticut, Rhode Island, Delaware, New Jersey excluded.

Results

The results obtained using ordinary least squares (OLS) to estimate the enrollment equation, excluding the demographic variables, are presented in column 1 of table 2. The independent variables together account for 84% (adjusted) of the interstate variation in the school enrollment rates of farm teenagers. All of the variables derived directly from the theory are statistically significant, indicating that parameters relating to agricultural production are significant determinants of farm school enrollment.

The negative sign of the coefficient of the farm value variable supports the hypothesis that the opportunity cost of school quantity,

[1] Various tests for the existence of heteroscedasticity were all rejected; the regression equations are unweighted.

Table 2. School Enrollment and Expenditure Regression Coefficients: U.S. Rural Farm Population, 1960

Independent Variable	Dependent Variable: School Enrollment[a]	School Enrollment	Per Pupil (x 10^2) Instructional Expenditures
Farm value (x 10^{-3})	−0.008	−0.001	0.095
	(3.97)	(2.18)	(2.81)
Nonfarm income (x 10^{-2})	0.022	0.028	1.42
	(2.24)	(2.33)	(0.91)
Total factor productivity change (%)	0.005	0.006	21.1
	(2.17)	(2.31)	(0.59)
Agricultural wage	1.00	0.609	11,434.1
	(3.60)	(1.17)	(2.32)
Male schooling attainment (35–44)	0.091	0.071	219.5
	(3.07)	(2.39)	(0.49)
Female schooling attainment (35–44)	0.024	0.008	205.7
	(0.49)	(0.15)	(0.21)
Urban unemployment rate (20–25)	−0.021	−0.038	−184.9
	(1.24)	(1.49)	(0.61)
Percentage nonwhite farm operators (35–44)	−0.002	−0.008	105.4
	(0.40)	(0.96)	(1.38)
Minimum lawful school-leaving age	0.011	0.008	216.2
	(0.11)	(0.55)	(1.27)
Percentage of 5–18 population aged 15–18			−53,937.5
			(1.98)
Proportion of total population aged 5–18			716.1
			(1.87)
Percentage of budget locally financed			−89.1
			(2.18)
Instructional expenditures per pupil (x 10^{-2})[b]		0.004	
		(0.91)	
Constant	4.29	4.12	41,820.6
	(4.22)	(4.21)	(1.76)
Estimation technique	OLS	2SLS	OLS
$\bar{R}^2$	0.837		0.716

Note: n = 44 states; Alaska, Hawaii, Connecticut, Rhode Island, Delaware, New Jersey excluded. *t*-values in parentheses.
[a] ln (1 − enrollment rate of farm 15–18 year olds); coefficient signs displayed are reversed.
[b] Endogenous variable.

the marginal value product of teenage children in farm production, is a significant deterrent to school attainment in the farm population. The farm value coefficient cannot be interpreted as evidence of the inferiority of child quality, as the coefficient of nonfarm income, which should provide a lower-bound estimate of the pure income effect, is significantly greater than zero.[2]

The positive coefficient of the productivity change variable suggests that farmers perceive that the returns to schooling are higher in settings where the pace of technological change is more rapid; a 10% increase in the rate of productivity change would be associated with a rise in the enrollment rate of farm teenagers of 5%. However, a plausible alternative hypothesis also consistent with this finding is that a high rate of technological change in agriculture may be associated with a lower demand for relatively unskilled labor, such as that of school-age children, since such technical change is likely to make the production process in the U.S. context more capital intensive.

The positive and significant coefficient of the wage rate of agricultural laborers suggests that educated farm children and hired laborers are substitutes in farm production and/or that higher agricultural wage rates enable farm children to finance their schooling by working as unskilled paid laborers both inside and outside the agricultural sector during school vacations.

The coefficients of both schooling attainment variables are positive. Only the coeffi-

[2] One component of off-farm income may be the earnings of children, which would impart a negative bias to the off-farm income coefficient in the enrollment equation.

cient of the schooling level of adult farm males is statistically significant, reflecting perhaps the predominance of males in agricultural production. The insignificance of the coefficients on the race or compulsory schooling variables suggests, respectively, that the school enrollment behavior of farm nonwhites and whites do not differ and state compulsory schooling laws do not significantly increase the school enrollment rates of farm teenagers.

If at the aggregate level interactions between school quantity and quality are important, the specification in column 1 is not the complete reduced form, as it omits some of the exogenous variables influencing the supply of school quality. To test for the dependence of school enrollment on aggregate school expenditures in the farm population, the school quality variable is added to the enrollment equation. However, because teenage school enrollment may possibly influence total per pupil public school expenditures, as found by Gustman and Pidot, two-stage least squares (2SLS) is used to obtain consistent parameter estimates. These estimates, displayed in column 2 of table 1, do not differ appreciably in either sign or significance from those obtained using OLS techniques in column 1. The one exception is the coefficient of the urban unemployment rate. It becomes statistically significant (10% level, two-tailed test), suggesting that decreases in employment opportunities in the nonagricultural sector significantly reduce the school enrollment rates of farm teenagers. The school expenditure coefficient does not attain statistical significance. The OLS school expenditure coefficient estimates are displayed in column 3 of table 2.[3] The set of independent variables explains approximately 72% (adjusted) of the interstate variance of rural per pupil instructional expenditures although only the coefficients of farm value and the agricultural wage of the variables implicated in the theoretical analysis attain statistical significance.[4] The sign of the latter, consistent with that in the enrollment equation, suggests that the demand for both rural-farm schooling inputs, school quantity and quality, is greater in areas where agricultural wage rates are high.

The most important result is the positive coefficient on farm value, which indicates that a rise in farm value of 10% results in an increase in rural-farm school expenditure of slightly over 1%. In conjunction with the results displayed in columns 1 and 2, this finding supports the hypothesis that increases in child farm productivity lead to the substitution of school quality for quantity in the farm population. The relative magnitudes of the mean elasticity estimates of farm value on the enrollment and school expenditure variables (−0.02 and 0.10, respectively), and the evidence obtained by Johnson and Stafford and others that the rates of return to school attainment (quantity) and quality are approximately equal, suggest that increases in farm value on net raise the overall quality level of farm children despite their attenuating effects on school enrollment. Given that child human capital is noninferior in an economic sense, this latter finding is also consistent with the theoretical analysis, in which the demands for school quantity and quality are derived from the demand for child quality.

Conclusion

The empirical results obtained based on U.S. state data generally support the theoretical framework (Rosenzweig 1973, 1977b). As a consequence of farm children's participation in farm production their marginal value product represents an important component of the cost of school quantity in the farm population such that increases in farm potential productivity reduce the enrollment rates of farm teenagers. At the same time, rural-farm school expenditures, which are unaffected by this opportunity cost, tend to rise with increases in potential farm productivity such that farm child quality on net is enhanced.

Evidence also suggests that the quantity of schooling in agriculture responds to both agricultural production and nonfarm parameters associated with the returns to schooling. A strong positive correlation is found between the school enrollment rates of farm teenagers and the rate of agricultural productivity change, a result consistent with the view that the returns to education in agriculture may be higher in situations characterized by disequilibrium because schooling increases the efficiency of technological adaptation. More research is needed, particularly on the direct

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[3] Because no identifying restrictions based on the available data were considered plausible, it was not possible to estimate the impact of farm school enrollment rates on rural school expenditures using 2SLS.

[4] The roles of the demographic and fiscal variables are discussed in detail in Rosenzweig 1977b.

contribution of the farm parents to the education of their children prior to, during, and after the schooling years, on the interplay of family size and education decisions, and on the transfer of pecuniary assets from parents to children.

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Household Capital Labor Ratios in Poor Farm Families

W. Keith Bryant

The major insights provided by the so-called "new home economics" are that household activities are productive in nature and that they involve the use of the traditional factors of production. The implications are far ranging and continue to be unpacked ten years after the formal treatments by Becker, Lancaster, and Muth. The particular implications pursued in this paper deal with the behavior of capital-labor ratios within the households, not the farms, of farm families. In particular, how do household capital-labor ratios of farm families respond to changes in the prices of family members' time, in family income, in family size, and in certain characteristics of the farm enterprise?

There are several reasons for interest in these responses. Principal among the implications are those analyzed by Linder to wit: as labor productivity rises with growth, labor becomes increasingly expensive to the family relative to capital, and family capital-labor ratios rise. Other implications have to do with the value of time spent in household activities (Gronau), the economic contribution of households to the national product (Siragelding), and the extent to which consumption over the household's life cycle is a function of the changing value of the household's time (Ghez and Becker). The reasons for analyzing farm families are that they are the most numerous of self-employed families making empirical work easier and that the implications of self-employment for household activities have been neglected.

In this paper two simple models of the farm family are outlined. One allows family members to work both on and off the farm, while the other provides for farm work only. Both the theoretical and empirical analyses neglect children's time and concentrate on the ratio of household capital to the wife's home time. (The models are developed in the paper by Bryant; copies are available from the author on request.) The ratios for poor farm families in three counties in Iowa and North Carolina are analyzed and discussed in the light of the models. The data for the empirical analysis come from the Rural Income Maintenance Experiment (RIME), which operated 1969–72 (Bryant and Hager).

Two Models of Farm Families

The Traditional Farm Family

For many farm families off-farm wage rates of the spouses, w_i ($i = h, s$; h denoting husband and s the wife), are lower than their marginal products on the farm. Thus, they allocate their available time (T_i) between household (A) and farm (F) activities. Both A and F are regarded as aggregate household and farm output, respectively. Their home times (T_{ia}) are combined with consumption goods (X) to produce commodities (A) from which the family derives satisfaction. They combine their farm times (T_{if}) with nontime farm inputs (K) in the production of farm products (F), which they sell at a price (p_f).

If X is considered to be household capital from which the service flow per period (t) is proportional to the stock, then X/T_{sa} is the household capital-labor ratio of interest. Family composition, type, and size denoted by the vector S, the tenure of the farm dwelling (D), and a vector of personal characteristics of the wife (Cs) all may have important effects on the productivities of X and T_{sa} as well as upon family preferences. Likewise, farm tenure (Tn) and farm size in terms of tillable acres (TA) affect the productivities of K and T_{if}. Thus, the demand functions for X and T_{sa} have as their arguments S, D, Cs, Tn, and TA as well as the prices of X, K and F, p_x, p_k, and p_f,

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R. Boisvert, J. Gerner, W. Huffman, R. Hutchens, and K. Stafford-Panourgia all helped in the development of this paper.

respectively, and unearned income (V). The ratio X/T_{sa} is a function of these same variables, i.e.,

$$(1) \quad X/T_{sa} = r_s^1(p_x, p_k, p_f, V; S, D, Cs, Tn, TA),$$

where $r_s^1(\cdot)$ is the ratio of the two demand functions. The variables in equation (1) after the semicolon represent characteristics on which the demands are conditioned. Net farm income does not appear in equation (1), being caught by variations in p_k and p_f.

The Part-Time Farm Family

For an increasing number of farm families, off-farm wage rates are higher than family members' marginal products on the farm, given some amount of farm work. Consequently, off-farm work competes with farm work. Family members divide their labor among home activities (T_{ia}), farm work (T_{if}), and market work (T_{iw}). This fact alters the demand functions for X and T_{sa} in two ways. First, off-farm market wage rates (w_i) enter the demand functions for both X and T_{sa}. Second, the prices of farm inputs and of farm outputs, as well as the variables on which farm production is conditioned, disappear as arguments in the demand functions and farm income (FY) appears, since off-farm work of both spouses makes the household and the farm separable. Thus, for part-time farm families in which both spouses work off the farm,

$$(2) \quad X/T_{sa} = r_s^2(w_s, w_h, FY, V; S, D, Cs).$$

Off-farm earnings, of course, affect the ratio via w_s and w_h.

Two intermediate cases exist in which one spouse works full-time on the farm while the other divides his/her labor among home, farm, and market work. In these cases the function for the wife's household capital-labor ratio is as follows:

$$(3) \quad X/T_{sa} = r_s^3(w_s, p_x, p_k, p_f, V; S, D, Cs, Tn, TA)$$

and

$$(4) \quad X/T_{sa} = r_s^4(w_h, p_x, p_k, p_f, V; S, D, Cs, Tn, TA),$$

where the wife and the husband, respectively, are employed in market work. Here, both off-farm earnings and farm income enter the functions via wage rates, prices, and the circumstances on which farm production is conditioned also appear as arguments.

The Data and The Variables

The data used to estimate the equations are on continuously married, husband-wife families in Calhoun and Pocahontas Counties, Iowa, and Duplin County, North Carolina, who participated in the RIME in 1970–72 (Bryant and Hager). Farm families are defined as those who completed the farm section of each quarterly interview throughout the experiment and who had no nonfarm business assets. Because data on farm work of wives were not collected in 1970, only data for 1971 and 1972 were used in this analysis. The subsample was divided into four subgroups corresponding to the cases analyzed in the previous section.

The means and standard deviations of variables used in the analysis for each family type are given in table 1. The definitions of some of the variables and their use in the analysis need elaboration. The dependent variable is the dollar value of the stock of consumer durables per hour of the wife's home time per year. Consumer durables exclude cars and include all appliances, furniture and furnishings, sporting equipment, lawn and garden tools, jewelry, dishes, etc. (see Bryant and Hager for further details). Home time is defined as the total time available to the wife per year (8,760 hours) minus her farm and market work time.

Families are either in the payments or the control group. Families in the payments group are eligible to receive experimental negative income tax welfare payments (NIT) of the form

$$(5) \quad NIT = G - \alpha Y,$$

if $Y < B$ and zero otherwise, where NIT is annual welfare payment, G is dollar amount of NIT if income (Y) is zero, α is the negative income tax rate, and B is breakeven income. Within the payments group different families are exposed to G's of 50%, 75%, and 100% of the family's poverty-line income and α's of 0.3, 0.5, and 0.7. A treatment variable taking on values of one if the family is in the payments group and zero if it is in the control group is included to take account of systematic differences between the two groups. G was included in the analysis in early fittings of the equations but was omitted when found to have no effect.

Table 1. Means and Standard Deviations of Variables Used in Analysis of Consumer Durables/Wife's Home Time Ratios of Poor Farm Families, 1971–72

	Family Type			
	Neither in Market Work	Both in Market Work	Wife in Market Work	Husband in Market Work
Stock of consumer durables	0.2349	0.2303	0.2470	0.2470
per hour wife's home time	(0.1160)	(0.1400)	(0.1228)	(0.1368)
1969 family income minus	4.3312	3.4688	3.5714	5.4347
wife's earned income ($1,000)	(2.4396)	(2.0744)	(2.4714)	(2.9739)
$(1-\alpha)w_s$ ($1)		0.8299	1.1901	
		(0.6852)	(1.6946)	
$(1-\alpha)w_h$ ($1)		1.6679		1.8041
		(0.9473)		(1.5452)
Year (1 if 1972)	0.5493	0.4706	0.5205	0.3784
	(0.5011)	(0.5012)	(0.5030)	(0.4917)
Race (1 if black)	0.1127	0.4622	0.2466	0.2162
	(0.3184)	(0.5007)	(0.4340)	(0.4173)
Region (1 if N.C.)	0.4507	0.7227	0.4932	0.5135
	(0.5011)	(0.4496)	(0.5034)	(0.5067)
Treatment (1 if payments)	0.6901	0.4622	0.4384	0.6486
	(0.4657)	(0.5007)	(0.4996)	(0.4840)
1 if head > 44 and no children	0.2958	0.1597	0.2466	0.0541
	(0.4596)	(0.3678)	(0.4340)	(0.2292)
1 if head > 44 and children	0.3239	0.4454	0.4247	0.3541
	(0.4713)	(0.4991)	(0.4977)	(0.4840)
Wife's age	44.2535	41.7311	41.5890	37.0000
	(9.8832)	(10.4927)	(9.3197)	(10.4323)
Wife's education	9.8873	9.6471	10.2192	9.7568
	(2.8463)	(2.6444)	(2.2376)	(3.2181)
Family size	3.9296	4.4538	4.1096	5.0541
	(1.7794)	(2.0492)	(1.6121)	(1.6150)
House tenure (1 if own)	0.4085	0.4370	0.5342	0.5135
	(0.4950)	(0.4981)	(0.5023)	(0.5067)
Tillable acres	160.1852	79.2300	139.8557	138.3400
	(122.4562)	(105.1446)	(123.3269)	(173.0500)
Acres owned	27.8451	15.4034	31.6028	26.1081
	(46.0632)	(38.1210)	(51.3056)	(43.0573)
Acres rented—share	127.0845	65.6555	103.1917	90.7838
	(133.5526)	(98.2342)	(111.5741)	(139.4834)
Acres rented—cash	28.9155	14.6975	24.6986	47.5676
	(60.3089)	(53.5625)	(47.1099)	(115.5128)
Acres rented—free	2.4366	1.8824	3.9452	2.6486
	(9.8803)	(7.8580)	(12.4637)	(8.6930)
Number of observations	71	119	73	37

Note: Numbers in parentheses are standard deviations.

Wage rates are adjusted for α but not for positive income tax rates. The wage rates are averages of wage rates reported during the year weighted by the times worked at each. As a result w_s is not independent of the random error terms in the equations in which it appears. Equations (2) and (3) are fitted by the method of instrumental variables (IV) with w_{st-1} as the instrument for w_{st}. Equations (1) and (4) are fitted by ordinary least squares (OLS).

No data on prices other than wage rates were collected. Race (1 if black), region (1 if N.C.), and year (1 if 1972) are included as variables to adjust for any such differences, some of which could be due to price differences. Dummy variables indexing head's age and the presence of children take account of family life cycle effects. The subsample does not include any childless families with the head under 45. The wife's age is not included as a variable because it is highly collinear with the life cycle dummies. Farm land is included either as total tillable acres or as acres by tenure arrangement.

The Empirical Analysis

The results of estimating the X/T_{sa} functions, equations (1) through (4), for each of the four subgroups are shown in table 2. All equations

Table 2. OLS and IV Estimates of Consumer Durables/Wife's Home Time Ratio Equations for Poor Farm Families in Iowa and North Carolina, 1971–72

	Family Type			
Independent Variables	Neither in Market Work	Both in Market Work[a]	Wife in Market Work[b]	Husband in Market Work
Income	0.0404	0.1773	0.0476	0.0633
	(0.0180)	(0.0883)	(0.0289)	(0.0341)
Income squared	−0.0034		−0.0055	−0.0047
	(0.0015)		(0.0032)	(0.0028)
$(1-\alpha)w_s$		0.2606	0.0600	
		(0.1730)	(0.0360)	
$(1-\alpha)w_h$		0.1387		−0.0190
		(0.1274)		(0.0170)
Year (1 if 1972)	−0.0009	0.0158	0.0710	0.0548
	(0.0258)	(0.0841)	(0.0316)	(0.0353)
Race (1 if black)	−0.0276	0.0177	−0.0306	−0.0061
	(0.0469)	(0.1107)	(0.0444)	(0.0524)
Region (1 if N.C.)	−0.1168	−0.1214	−0.0464	0.0720
	(0.0473)	(0.1811)	(0.0534)	(0.1020)
Treatment (1 if payments)	0.0408	−0.1306	0.0703	−0.0126
	(0.0277)	(0.1425)	(0.0372)	(0.0453)
1 if head > 44 and no children	0.0309	−0.1477	0.0382	−0.1863
	(0.0613)	(0.2087)	(0.0624)	(0.1196)
1 if head > 44 and children	−0.0299	−0.2601	−0.0343	−0.1107
	(0.0418)	(0.1075)	(0.0406)	(0.0713)
Wife's education		0.3819		
		(0.1622)		
Family size	0.0227	0.2006	0.0368	0.0050
	(0.0139)	(0.1581)	(0.0143)	(0.0134)
House tenure (1 if own)	0.0749	0.1816		0.1104
	(0.0418)	(0.1072)		(0.1034)
Gross value of home			−0.0059	
			(0.0044)	
Tillable acres	−0.0001	0.0416	−0.00002	
	(0.0002)	(0.0493)	(0.00024)	
Acres owned				0.0005
				(0.0005)
Acres rented—share				0.0006
				(0.0002)
Acres rented—cash				0.0004
				(0.0003)
Acres rented—free				0.0053
				(0.0035)
Constant	0.0620	−2.9365	−0.0707	−0.0665
F-ratio	2.9544	8.4972	1.9392	3.6090
$\bar{R}^2$	0.2350			0.5209
Number of observations	71	119	73	37

Note: Numbers in parentheses are standard errors.
[a] Estimated by instrumental variables, and continuous variables are expressed in natural logarithms.
[b] Estimated by instrumental variables.

fit the data surprisingly well given that the data are essentially cross section. The traditional farm family equation fits least well. Both the equations fitted by IV account for over 45% of the variance in X/T_{sa}.

A major hypothesis flowing out of the discussion of the models is that farm production inputs help determine household capital-labor ratios for all but the family in which both spouses have off-farm work.[1] The evidence is mixed. In only one of the three cases (columns 1, 3, and 4 of table 2) in which tillable acres or acres by tenure arrangement are expected to affect the durables/wife's home time ratio are the expectations fulfilled. One reason might be that acres farmed is a proxy for per-

[1] There are four exceptions to this result. They are if (*a*) the family physically consumes some farm production, i.e., if *F* is treated as *X*; (*b*) nonlabor farm inputs are the same as consumption goods; e.g., if credit for farm and home use are indistinguishable; (*c*) the marginal product of farm labor is everywhere lower than the wage rate but spouses cannot obtain all the income they desire from wage work because, for instance, hours of work are limited; and (*d*) the family derives satisfaction from farming independent of any farm output it physically consumes (Bryant).

manent income, and its effect is thus confounded with that of income. Another, less probable reason might be that the farm production function is additive in K and T_{tf}.

Folklore about farm families, and poor ones in particular, asserts that they consume much of their own product and derive much utility from farming. If such was the case farm production inputs would importantly influence the household capital-labor ratios of all four family types (Bryant). The findings provide little empirical support for such ideas.

In most of the work on the economics of home production homotheticity has been assumed (Ghez and Becker, Linder, Michael). In the present context homotheticity implies zero income elasticities of demand for X/T_{sa}. The income elasticity of demand for the ratio is

$$(6) \qquad \eta_{(x/s)} = \eta_x - \eta_s,$$

where η denotes the income elasticity, x, the stock of consumer durables, and s, the wife's home time. Evaluated at the means where relevant the estimated $\eta_{x/sa}$ are 0.21, 0.18, 0.12, and 0.28 for the subgroups represented by equations (1) through (4), respectively. All are computed from coefficients significantly different from zero at the 0.10 level or lower. Homotheticity is a strong assumption, and there is no question that it can be rejected on the basis of this evidence. Clearly, for poor rural families the income elasticity of demand for consumer durables is higher than the demand for the wife's home time. As income increases the household capital-labor ratio increases.

The effects of wage rates on the household capital-labor ratio are of interest. The wife's wage rate elasticity of demand for the ratio of household capital to the wife's home time is

$$(7) \quad E_{(x/s)s} = \beta_s(\sigma_{xs} - \sigma_{ss}) + \beta_s(\eta_x - \eta_s),$$

where β is the market work budget share and σ is the Allen partial elasticity of substitution between subscripted goods. $\sigma_{ss} < 0$ and $\sigma_{xs} \gtreqless 0$ as durables and wife's home time are substitutes, independent, or complements, respectively. Similarly, the husband's wage rate elasticity of demand for the ratio is

$$(8) \quad E_{(x/s)h} = \beta_h(\sigma_{xh} - \sigma_{sh}) + \beta_h(\eta_x - \eta_s).$$

The present study provides two estimates of each of these wage rate elasticities. Estimates for the elasticity in equation (7) are 0.26 and 0.29 for the subsamples with both husband and wife and just the wife engaged in market work, respectively. Estimates for the elasticity in equation (8) are 0.14 and −0.14 for the subsample with both husband and wife and just the husband engaged in market work, respectively. Both wife's wage rate elasticities are computed from coefficients at least one-and-one-half times their respective standard errors, while the husband's wage rate elasticities are computed from coefficients about the same size as their standard errors. The elasticity of the ratio with respect to w_h can be taken as zero, a finding consistent with current knowledge about labor supply and home production. Estimates of $(\sigma_{xs} - \sigma_{ss})$ and of the compensated wife's wage rate elasticity, $E^c_{(x/s)s} = \beta_s(\sigma_{xs} - \sigma_{ss})$, are 2.2 and 0.24, respectively, for families in which both spouses have wage work. For those families in which only the wife has wage work, estimates of $(\sigma_{xs} - \sigma_{ss})$ and $E^c_{(x/s)s}$ are 1.81 and 0.27, respectively. In both cases, home activities become more capital intensive with respect to the wife's home time as her wage rate rises. Both substitution and income effects, therefore, lead to a capital intensification of household activities.

Wife's education has a significant positive effect on the ratio of consumer durables to the wife's home time, for the case in which both spouses have off-farm work. Education could be picking up part of the own-wage rate effect as w_s and wife's education are highly correlated. Also, it is likely that education has life style effects as well as effects on the productivity of the wife's home time (Michael, Morris).

As family size rises the ratio of durables to the wife's home time can be expected to rise. There are economies of size with respect to major appliances (washers, driers, etc.) stemming from technical indivisibilities. As family size rises, especially above two, families can take advantage of these economies. Also, in large families, older children's time can substitute for the wife's home time leading to a capital intensification with respect to the wife's home time but not necessarily with respect to total family home time. The evidence for such effects is clear with respect to farm families in which only the wife has market work and is less clear for the traditional farm family and for families in which both spouses have market work. Evidence does not exist for the farm family in which only the husband has off-farm work.

Family life cycle effects are caught by the dummy variables indexing the head's age and the presence of children. The coefficients provide weak evidence for a labor intensification of household activities in older families with children as the stock of durables purchased after family formation depreciates out and, perhaps, as some of the wife's home time is replaced by the children's.

In two of the family types home ownership serves to increase the ratio of consumer durables to the wife's home time. This is in conflict with the evidence that the gross value of the home, if owned, appears to depress the durables/wife's home time ratio in farm families in which only the wife has off-farm employment.

Summary

In summary, one can conclude, first, the household activities of poor farm families experience capital intensification relative to the wife's time as family income rises. This seems reasonable since one expects poor families to value goods over time relatively. This finding also provides evidence against the assumption of homotheticity. A test of the proposition that the total goods-time ratio is unaffected by income remains to be conducted. Second, household activities also undergo capital intensification as the value of the wife's time increases. Here, both substitution and income effects appear to augment each other raising the stock of durables relative to the wife's home time. Third, while the theoretical roles farm production inputs play in determining household capital-labor ratios were specified, the empirical evidence was, at best, blurred. Alternative hypotheses having to do with the subsistence nature of poor farms and that they derive utility from farming fared no better. Considerable more research of such questions over the whole range of the income distribution and for other types of families needs to be done.

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Antitrust Policy in Agriculture
(Ronald D. Knutson, Texas A&M University Chairman)

Antitrust Issues in the Food Industries

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The United States is unique among countries of the world for its strong reliance on antitrust as its main public policy vehicle for regulating business. In the U.S. economy, the market is extant over almost 90% of the production of goods and services, while direct government regulation encompasses a little more than a tenth (Sherer, p. 519). Aside from government regulations to protect the environment, worker safety, and a number of other aspects of company conduct, the free market sector is essentially self-regulating with the government acting only infrequently and very selectively as a policeman to ensure that fair and open competition prevails.

The history of antitrust has been mostly one of public indifference. However, the last five years, and especially this election year, have seen at least a minor ground swell of interest develop. This interest reflects frustration over the prolonged period during which the economy has experienced simultaneously high inflation and high unemployment rates.

In 1971, the perceived failure of markets to operate without uncontrollable inflation and high employment saw the Congress and the most laissez faire national administration in two generations of American politics opt for a rigid system of price controls. The vestiges of that system lasted until April 1974. Abhorrence of regulation by the administration together with the unsure success of its price control program saw a major increase in the rhetoric supporting strong antitrust enforcement to make markets more competitive and self-regulating.

The wave of food price increases that began in 1972 caused food to be a focal point of the public concern. Both the Federal Trade Commission (FTC) and the Department of Justice responded to the concern by increasing dramatically the amount of their resources spent on investigations involving food processing and retailing companies. In 1975, the FTC spent about a fifth of its total antitrust resources in the area. Because of this high level of activity, it is particularly appropriate that the American Agricultural Economics Association should consider the antitrust policy in agriculture.

I discuss antitrust issues relating to the food marketing industries. In so doing, I limit myself to economic issues even though many people would argue, and correctly so, that the antitrust laws are deeply rooted in social philosophy. In limiting the discussion to antitrust issues relating to competitive efficiency, I focus on the potential competitive problems identified in the economic literature describing the structure and performance trends in the food manufacturing industries and food retailing industry and on the group of issues that are perceived by antitrust agencies in their enforcement activities. The latter differ from the former because of operational limitations imposed on the agencies by the antitrust statutes and court interpretations and by the attitudes and philosophies of agency administrators and staff.

Structure Performance Issues in Food Manufacturing

I see the following as anticompetitive trends in food manufacturing and the major economic issues to be addressed by antitrust policy. The number of food manufacturers is declining rapidly, and the rate of exit is rising (Dixon, table 2), in sharp contrast to all manufacturing

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where the number of companies has been increasing. The first post-World War II quinquennial *Census of Manufacturers* in 1947 enumerated over 40,000 companies in food manufacturing. In the most recent census year, 1972, this number was 22,172. The decline in company numbers is widely dispersed among the food industries (U.S. Dep. Commerce 1975b, table 2). Whereas at the beginning of the post-World War II era, it was mainly small companies that were disappearing, the most recent decade has seen the trend increasingly encompass medium-size and larger companies. A projection of current company disappearance rates indicates that half of the current number of food manufacturers will disappear within the next decade.

The decline in company numbers is effecting the size distribution of companies. Average industry concentration in the food and kindred products manufacturing industries is high relative to most other industries. Census concentration data indicates that about three-quarters of all value added by the food industry comes from oligopolies as defined by Bain's classification system and about 30% comes from highly concentrated oligopolies (U.S. Dep. Commerce 1975a). An accumulating body of statistical analyses shows these oligopolistic industry categories having higher profits and cost-price margins than competitively structured industries (Weiss).

Available evidence indicates a trend toward even higher concentration levels. There was a particularly sharp increase between the two most recent census years, 1967 and 1972. This followed slower increases between the previous postwar census years (Parker, table 3).

Although the average level of concentration in the food industries is high enough to suggest the presence of competitive problems, there is a great diversity of concentration levels among the 47 four-digit food industries and the 130 food product classes. In general, concentration has been declining in those food manufacturing industries that produce products for other industries (producer goods industries) and also in low differentiation consumer product industries like meat packing (Mueller). Conversely, concentration is high and increasing in industries where product differentiation is important.

Besides the rising levels of concentration within individual industries, there is high and increasing overall concentration of total food and kindred products manufacturing activity. The control by a few very large enterprises extends especially to those positions in the individual food industries that have potential for market power. Since large market share positions are increasingly important to the structures of individual industries, the concentration of these positions in the hands of about fifty very large companies of the total of 22,000 food manufacturers is significant.

The share of assets of all corporations primarily classified as food manufacturers accounted for by the fifty largest was 56% in 1974, an increase from 41% in 1950 (Dixon, p. 3). This is an understatement of the upward trend because in the early 1970s the data were adjusted to exclude the holdings of foreign assets, which were more extensively concentrated in the hands of larger corporations (Penn).

In 1963, when the fifty largest food companies controlled about 48% of total food manufacturing assets, a special census tabulation showed that they controlled about 70% of the four leading producing positions in all of the food industries and product classes defined by the Bureau of the Census (NCFM 1966b, pp. 25, 66, and 221). The same tabulation showed that large food manufacturers tend to occupy positions in concentrated industries more often than in less concentrated industries (p. 49).

The tabulation showed, further, that the fifty largest food manufacturing companies of 1963 each held an average of over eleven top four positions in four-digit industries, including nonfood industries (p. 50). This was an increase from nine in 1954. Data more recent than 1963 are not available; however, the high rate of large food company acquisitions by other large food products companies since 1963 suggests that the concentration of potential market power positions with the largest food manufacturing companies has increased.

In addition to holding entrenched positions, the fifty largest food manufacturing companies account for nearly all of the most important media advertising in the food area. In 1964, they had 90% of all network TV advertising of food products. In addition, they accounted for most of the field sales force personnel employed by food manufacturers. Their strong positions in markets plus their diversity both within the food area and in other grocery store products give the largest food manufacturers access to strategies such as reciprocity and full-time forcing that smaller less diversified

firms cannot employ. The largest companies, because of access to shelf space and a capacity to reach consumers with effective promotional efforts, are clearly a class by themselves. They are the leading potential entrants in all food and kindred industries and particularly in those industries that are oligopolistically structured.

Impact of Food Industry Mergers

The increase in aggregate concentration with the largest food manufacturers is strongly related to mergers. When food company mergers were examined in 1966, it was found that were it not for mergers the combined share of assets of the fifty largest food manufacturers would have declined between 1950 and 1965 (NCFM 1966b, p. 120). Although the data subsequent to 1965 have not been analyzed, the brisk continuation of food company mergers, especially of larger companies, suggests that mergers are continuing to contribute to the increasing overall concentration. Since 1965, the proportion of large food companies acquired relative to all large manufacturing companies acquired increased. Each year mergers have eliminated a significant percentage of the remaining number of independent medium-sized and larger food manufacturers.

Although most acquisitions by the largest food manufacturers during the last two decades were product extension rather than horizontal, they still had the likely effect of increasing concentration levels in the industries involved. Firms acquired by the fifty largest food manufacturers were typically larger firms and often were among the four leading producers in one or more food product areas (NCFM 1966b, pp. 126–27). Many were also substantial advertisers of well-known food product brands. However, within a year after acquisition the acquiring companies, on the average, doubled the amount of advertising expenditures for the acquired brands, with television advertising showing the greatest percentage increase (NCFM 1966b, pp. 125–27). Though market share change data are not available, it is hard to conceive that the additional advertising did not increase market shares and the level of industry concentration.

Another interesting fact reported in the 1966 study was that acquisition was almost the sole route by which the largest companies entered new industries. FTC analysis of detailed product data for the twenty-five largest food manufacturers indicated that nearly 90% of the product areas entered by the companies were directly traceable to merger (p. 124). The very low research and development expenditures of the largest food manufacturers are consistent with this finding (p. 80). In addition, food manufacturing was found to be the only one of the twenty major industrial groups in manufacturing where there was an inverse relationship between size of firm and the number of research and development personnel per 1,000 employees. The picture that emerges from these data and others, such as use of field sales force personnel and advertising, is that usually large food manufacturers move into new products only after those products are first developed by smaller firms. The acquiring corporations then enhance the market positions they acquired through intensive advertising and other product differentiation strategies.

For the last several years average profit rates of food manufacturers have been higher than those of other manufacturers (Parker). More important is the upward trend relative to other manufacturers that has been sustained for a quarter century. Profits of food manufacturers are strongly related to industry concentration levels, individual company market shares in their industries, and industry advertising expenditures. Profit rates are found to average three times higher when these variables took on high values rather than low values (FTC 1969b, p. 7).

Structure Performance Issues in Food Retailing

Grocery retailing has experienced a major shift toward larger companies since World War II. This shift, which generally followed the "supermarket revolution" of the 1930s and 1940s, saw concentration increase both in metropolitan area markets and for the nation as a whole.

Local area concentration is of prime importance because local areas are the main arenas of competition for consumer purchases. Few consumers consider traveling to a different city to buy groceries. Large metropolitan areas, however, are often too broadly defined for purposes of consumer grocery purchases. Many contain significant submarkets that are geographically distinct and are served by separate advertising media. Supermarkets and small convenience stores are also separate submarkets. For these reasons, grocery store

concentration ratios for whole metropolitan areas should be considered minimum estimates of concentration.

The unweighted average four-firm concentration ratio for over 200 U.S. standard metropolitan statistical areas (SMSA's) increased from 45% in 1954 to 52% in 1972 (Parker). Eight-firm and twenty-firm concentration experienced much greater rates of increase. Concentration in large SMSA's made an especially large jump between 1967 and 1972 (Parker).

Concentration levels vary considerably between SMSA's. Some SMSA's have had consistently low concentration ratios. Others, however, including some of the nation's largest cities, have concentration levels as high or higher than the most concentrated manufacturing industries.

National concentration becomes important in the procurement of grocery products and has shown a strong upward trend over the post-World War II period. Just twenty large grocery chains accounted for 37% of total grocery store sales in the United States in 1975 (Parker). This was an increase of more than a third over the 27% controlled by the twenty largest chains in 1948.

Major studies of grocery retailing, including those of the National Commission on Food Marketing (NCFM 1966a, p. 75) and the Federal Trade Commission (FTC 1966, chap. 11), have found significant barriers to entry and significant pecuniary advantages of size to the largest established food chains in local markets. Pecuniary advantages of large size are especially important in newspaper advertising and in procurement. The largest established chains in cities and regions also have advantages in the selection of store sites and, when their market shares are high, they have neighborhood pricing strategies available to them that can discourage new entrants (FTC 1969a). Given these advantages, little hope exists for a quick erosion of the very high levels of grocery store sales concentration in some metropolitan areas or a dampening of the upward trend that has brought the average concentration level for the over 200 U.S. metropolitan areas to a point that is statistically associated with competition problems.

Food Chain Profits and Margins

Long-run profit rates of food retailers averaged about 50% higher than the rate earned by other retailers for the twenty years prior to the A&P-WEO discount program that began in 1972 (FTC 1975). Since then the level and the trend of food chain profits has been subject to a number of unusual temporary occurrences including changes in accounting practices. However, recent profit rates appear to be more consistent with the previous long-run trend.

Food chain average gross margins and profit rates are strongly related to market share levels (Parker). On the average the price consumers pay for food retailing services goes up as retailer's market share in a city increases. On the average, large food chains report losses in their low market share areas. This indicates significant subsidization by large chains to their low market share cities from profits earned in high market share cities. My estimate of the total amount of the subsidy for the fifty largest chains based on current sales and profit figures is between $250 million and $1 billion (Parker).

Food chain gross margins increased significantly in the decade and a half between the early 1950s and the late 1960s ending at a level equal to what they had been prior to the supermarket revolution. A principal reason for the increase was the redirection of grocery retailing competition to expensive forms of nonprice competition. For the decade between 1955 and 1964, the period when percentage gross margins grew the most, 41% of the increase in supermarket operating costs was due to the increased costs of trading stamps and other promotional expenses according to the final report of the National Commission on Food Marketing (1966a, p. 78). In recent years, overstoring (excess capacity), a characteristic often found in oligopolistic industries, has resulted in higher operating costs for food chains. Between 1969 and 1974, sales per square foot (in real dollars) for supermarkets reporting to the Supermarket Institute declined about 20% (p. 11). A Canadian government report estimates that "overstoring" by food retailers in Canada caused consumers "to pay an average of 4 cents more than necessary per dollar of sales" (Canada, p. 200).

An extensive merger movement in food retailing that began in the 1950s was part of the underlying cause of the shift from price competition to nonprice forms of competition. The merger movement and the increasing trend in percentage gross margins began almost simul-

taneously. The effect of the merger movement was to eliminate the procompetitive force of actual and potential entry of chains from other cities. This kind of entry is a a very significant force directing food retailers to compete on a price basis. When large chains chose the merger route for expanding into new markets, the price rivalry associated with entry was avoided. In the mid-1960s, court victories in federal antitrust cases curtailed large market extension mergers.

Several of the most active acquiring companies of the 1950s and 1960s continued their growth objectives after the new merger enforcement policy was achieved (FTC 1971, pp. 14–15). In place of buying market shares of going concerns, these chains were forced to enter new markets de novo through price competition. Often they accomplished this by promoting themselves as "discounters" and thus popularized that term in grocery retailing. Since 1965, gross margins have not only stopped going up but dropped by slightly more than a percentage point (Parker). Considering that annual grocery store sales are currently over $150 billion a year, savings to consumers due to the decline in margins are in the area of $1.5 billion a year. Calculated savings would be substantially higher if the previous increasing trend in margins were projected forward.

The issues that emerge from the structure and performance trends in the food industries are (*a*) high and increasing market concentration, (*b*) significant degrees of product differentiation, and (*c*) moderately difficult entry. In many food manufacturing industries, entry can be achieved only through high product differentiation costs that are passed on to consumers in the form of higher prices. A fourth issue, in both food manufacturing and retailing, is the positions of market power concentrated with just a few large companies. This concentration provides strategies to those companies that are used to insulate them from the competition of medium-sized and smaller firms in their industries. Prospects of an erosion of these advantages without public policy intervention are dim. The structures of most food manufacturing and retailing markets are likely to continue their trend toward more tightly oligopolistic markets.

Antitrust Enforcement Issues

Antitrust enforcement is accomplished within a highly legal framework. The main vehicle is case-by-case litigation. While economists may perceive concentration as an economic issue and proceed to construct a structural model for improved efficiency, antitrust enforcement is constrained from such a direct approach both by the conduct-oriented language of the antitrust laws (Kaysen and Turner, chap. 3) and by court interpretations. Enforcement agencies deal with the problem of concentration primarily by reacting to acts and practices described in statutes such as mergers, predatory practices, and other concentration enhancing activities. Only recently has the FTC taken a first, cautiously chosen step to deal with the problem of concentration more directly through a deconcentration remedy connected with a shared monopoly case (*Trade Reg. Rep.*). The investigation leading to that case, which is against the largest breakfast cereal producers, was begun in 1968, and the final court ruling affirming the deconcentration remedy, if it should occur, may be as far away as five to ten years. Until then, unless there is a change in the law, the legal ground for a direct attack on concentration is tenuous.

Mergers

Merger enforcement policy probably has more impact on industry structure and performance than any other single area of enforcement. FTC merger enforcement guidelines are in effect in both the food manufacturing and food retailing areas. These guidelines, issued in the late 1960s, spell out the specific characteristics of mergers that the commission considers most likely to cause competitive problems.

The issues in horizontal merger cases are (*a*) the definition of the market, (*b*) market share and concentration levels, and (*c*) the health of the acquired and acquiring companies. In recent years, however, performance variables have taken an added importance in determining the probable effects of a proposed merger. In net the consideration of these additional factors has been to weed out merger investigations that would have been conducted on the basis of structural data alone.

In product extension mergers, which is the principal category of large mergers in food manufacturing, the degree of relatedness of acquired and acquiring companies is the major issue in determining potential competition. The required degree of relatedness has probably increased in recent years. The concept of potential competition is generally under attack

on the grounds that the standards for identifying potential competitors are too vague.

Market extension mergers are the main category of mergers in food retailing. A market extension merger is where a company in one geographic area expands by acquiring a firm in another geographic area. A basic question in a market extension merger is the threshold distance for defining a potential entrant. A related issue is that of distinguishing between a toe-hold acquisition and an acquisition of a significant participant in a market.

Vertical merger cases are not currently popular with antitrust agencies in my opinion. This is because of increasing criticism urging that a vertical merger must involve a very large share of a market before it represents substantial foreclosure or poses a substantial threat of possible dual distribution predation.

No conglomerate merger case has been brought since 1969 nor, in my opinion, is one likely to be brought by either the FTC or the Antitrust Division of the Justice Department. The principal conglomerate merger theories of deep pocket and cross-subsidization, reciprocity, and entrenchment of leading firms have fallen on hard times with respect to enforcement activity.

Conduct

Conduct includes such antitrust areas as price fixing, territorial restrictions, and price discrimination. In the conduct area per se doctrines previously focused almost exclusively on narrow legal issues rather than on more encompassing economic models. This is changing, and for the last four years screening of actions in these areas and requests for use of compulsory process have been made by an evaluation committee that is jointly staffed by economists and lawyers. Within the overall conduct area is an increasing zeal for price-fixing cases and a declining zeal for most other per se cases.

The main support of price-fixing cases, now, as always, is the hot piece of evidence that proves intent. This is usually obtained from informers or through file searches. Identical bid information also has been used in a number of cases. The problem of detecting price fixes, however, remains serious, and new antennae systems for discovering price fixes are needed.

Price discrimination (Robinson-Patmen Act) cases have declined dramatically in the last five years. In my judgment, the reason for the decline at the FTC, which in the past brought most Robinson-Patmen Act cases, is an increasing belief on the part of the economics staff that discriminatory prices are usually no more than a payment for shelf space, which is a scarce commodity that manufacturers should pay for. Secondly, price differentials to large buyers are believed to occur mainly because a market is soft, and price cuts to the large buyers are thought to simply reflect a prediction of a general price decline. In this context price cuts to large buyers are believed to speed up the general decline and therefore are a beneficial contribution to efficient market operation and should not be prosecuted even though they may be discriminatory and have potentially anticompetitive effects. Some critics of the Robinson-Patman Act have gone further by saying that the history of FTC enforcement has often buttressed existing price fixes. In my judgment very little is known about the effect of Robinson-Patman Act enforcement, and an objective study of it is badly needed.

Predation, including primarily line price discrimination, is being increasingly discounted as an anticompetitive practice because most benefits are assumed to be external to the company engaging in the predation. Also, there is a presumption of a general ease of reentry because productive assets of the target companies of the predation usually can be easily restored to use. The critical challenge to an attorney proposing a predation case is a showing that the predatory firm had a cost-benefit ratio for the use of predation that justified its employment.

Territorial restriction cases are usually persued on a straightforward per se basis. The future of territorial restriction cases in the food area is uncertain because of an effort in Congress to pass a law exempting food retailing and soft drink bottlers from prosecution on a per se basis.

A recent area of interest to the commission, which may have a profound effect on agriculture, is the analysis of agricultural cooperatives and federal marketing orders. Although some current investigations are being conducted for possible legal actions, there is a feeling on the part of the staff that the cooperative exemption may constitute a significant hinderance to competition and that federal market orders distort markets causing a serious waste of agricultural resources.

Conclusions

I think the most serious weakness of antitrust enforcement in the food area is the lack of up-to-date data and analyses. It has been a decade since the National Commission on Food Marketing and the FTC studies of the 1960s began to scratch the surface. Available current data suggest worsening structure and performance trends. We need a thorough review of antitrust policy in the food area.

Unfortunately, identifying the need will not automatically result in its being filled. I believe it is time to establish a national center for evaluation and support of antitrust policy in the food area. The center should be staffed by a critical mass of people with expertise in industrial organization problems in the food industries. They should be in a research environment that has continuity over time and one that is isolated by distance from day-to-day enforcement activities. It would be appropriate if the AAEA would propose establishing such a center at a university. The center should be funded by Congress and should have access to federally collected data. Committees of Congress should use the center as an arm to help them more efficiently perform their legislative functions and oversight over the federal antitrust agencies.

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Antitrust—A Route to Centralized Governmental Planning?

Luther C. McKinney and Donald A. Washburn

It is popular to contend that bold new antitrust theories will eliminate numerous social problems. We are witnessing a flood of proposals to cure inflation, unemployment, productivity shortfalls, advertising abuses, nutritional deficiencies, industrial concentration, and almost every conceivable economic difficulty (U.S. Congress, Senate 1976a, b; House 1976; *Trade Reg. Rep.* 1973a, para. 20388, pp. 20269–71). Unquestioning application and testing of these patent-medicine claims in the food industry are leading to counterproductive, centralized governmental planning in the guise of antitrust policy. Hence, we would urge every American to critically consider the merits of emerging antitrust policy rather than accept it at face value.

Antitrust policy has historically developed as a unique mixture of politics, economics, and law. Over an eighty-six-year period, Congress has generally legislated a national economic policy of free competition. Economists have joined in an attempt to define a concept of free competition worthy of achievement. Lawyers, as advocates and judges, have engaged in a case-by-case interpretation of these laws and theories.

The policy originated in 1890 with the Sherman Antitrust Act, which requires each firm to make its business decisions independently and to avoid monopolization or attempts to monopolize. Next, Congress, in response to claims that the Sherman Act was too vague (Henderson; U.S. Congress, Senate 1914a, 1913; House 1914), enacted the Federal Trade Commission Act outlawing "unfair methods of competition" and also passed the Clayton Antitrust Act prohibiting, among other things, acquisitions and price discrimination that may substantially lessen competition or tend to create a monopoly.

In 1936, the Clayton Act was amended by an anti-chain store bill known as the Robinson-Patman Act to more specifically prohibit discriminations in price, service, or facilities in an effort to stop concessions demanded of food suppliers by large chain stores. In 1938, the Federal Trade Commission Act was amended to prohibit deceptive acts and practices.

Any objective ranking of these acts in terms of ability to preserve the fundamental aspects of competition affecting both the competitor and the consumer would rank the Sherman Act prohibitions against price fixing and other per se illegal restraints of trade in first place by a wide margin. The Sherman Act prohibitions against illegally obtaining or maintaining the market power to control prices or exclude competitors have been effective as well, but time consuming to enforce due to the complex economic issues involved.

The remainder of what is popularly regarded as U.S. antitrust legislation reads well on paper but is the subject of mixed reviews from a practical standpoint. Theoretically, an antimerger statute intended to nip incipient monopolies in the bud is difficult to criticize. Likewise, the concept of preventing discrimination or the inducement thereof when it is destructive of competition is appealing. The problem has been one of application. All too often such legislation has been viewed as a tool to maintain the status quo in the face of inevitable and desirable change.

The Clayton, Federal Trade Commission (FTC), and Robinson-Patman Acts are all based on the idea that public interest is best served by preserving many small firms operating in a purely competitive market (U.S. Congress, Senate 1913, 1914b). Obviously, that policy has not been literally enforced, or we would all be associated with World War I horse and buggy industries instead of a modern, international marketplace requiring economies of scale to survive.

A realistic compromise between theory and

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practical reality has resulted from a strenuous adversary process. For example, countless antitrust enforcement resources were expended over many years out of fear that the rapid development of a more efficient food distribution system would destroy small food retailers (*Federal Reporter* 1939, pp. 667–79; *U.S. Supreme Court Reports* 1960, pp. 166–89; 1968, pp. 341–64). Nevertheless, the trend to modern methods prevailed. Efficient small stores offering convenience survived, and the facts clearly establish that the consumer is significantly benefited where scale economies accrue (Kunreuther). Indeed, members of the federal agencies who fought this delaying action now admit that in the food industry "divestiture or deconcentration . . . could well raise prices and injure consumer welfare" (*Antitrust and Trade Reg. Rep.* 1974, p. A-10).[1]

In spite of the inconsistencies between theory and reality, a gradual give-and-take, case-by-case interpretation of the four underlying statutes resulted in evolutionary changes that had no crippling or shock effect on business generally, since there was sufficient time and opportunity to present opposing views and to adjust to policy shifts.

The regulators, however, were not totally satisfied with that approach. They desired a more immediate involvement in business decisions. Businessmen provided an escape for the administrators by demanding more certainty regarding the applicability of antitrust policy. Consequently, the issuance of government guidelines became popular.[2] FTC Trade Regulation Rules, with binding legal effect, cover numerous areas (*Federal Reporter* 1973, pp. 672–709). Recently, in a further effort to avoid case-by-case interpretations, the FTC sought and secured legislation providing that a cease and desist order against one industry member subjects other industry members to a $10,000 per day penalty, providing they had notice of the order and engaged in acts that would be a violation of such order (see, for instance, P.L. 93-637).

The result has been to arm the regulators with strong procedural devices to minimize the role of the historical adversary system of policy evolution. Since the penalties for violation are so immense, many business people fear incurring the wrath of these regulatory czars. As a result, desirable changes in market structure, dictated by changing circumstances, may be slowed substantially to the possible detriment of consumer welfare. Still, our business system has been sufficiently strong to endure. We suspect that change can still occur as needed, even under the guidelines approach to antitrust policy, to permit continuation of the efficient system we have come to expect.

The same cannot be said for the move now afoot to establish the next generation of antitrust policy. Reduced to its lowest common denominator, that policy would allow the government to restructure through divestiture orders any industry deemed to be too concentrated. Current examples of the FTC's attempts to create such a policy include suits against the four largest ready-to-eat cereal manufacturers (see below) and the eight largest oil marketers in the United States (*Trade Reg. Rep.* 1973a, para. 20388, pp. 20269–71) for so-called "shared monopolies." If these proposals succeed, they will outlaw the market structures of about one-third of U.S. industry ("Antitrust: Snap. Crackle and Pop").[3] The shock of such a change would be too great for our business community to absorb without some unpleasant effects.

The FTC's assault in the cereal case goes to the very heart of numerous segments of the food industry where many companies find themselves among the top four to eight firms accounting for more than half of a segment's sales (U.S. Congress, House 1976; U.S. Dep. Commerce). In 1972, the FTC charged that Kellogg, General Mills, General Foods, and Quaker Oats were participating in a "shared monopoly" of the ready-to-eat (RTE) cereal industry. The charges were said to be justified, based on the limited number of firms in the business and their aggregate market share—an approach that had no prior basis in either legislation or case law. A few of the

[1] Enforcement of the Robinson-Patman Act provides countless illustrations. For instance, food retailers, over the years, who operated truck fleets were forced to run empty on return trips because the FTC viewed back-haul allowances by suppliers as discriminatory. While this area of policy is still murky, pressure to improve productivity has forced the agency to begin clarifying its position on the subject (*Trade Reg. Rep.* 1973b, para. 18089, pp. 20537–38, paras. 20498, 20850, 21031; FTC).

[2] For example, the FTC issues restrictive trade rules governing prospective mergers in the dairy and grocery manufacturing industries (*Trade Reg. Rep.* 1973b, para. 4532, pp. 6914–16; 1968b, para. 4530, pp. 6908–13). Similarly, the Justice Department issued its own merger guidelines (*Trade Reg. Rep.* 1968a, para. 4510, pp. 6881–89).

[3] Publicity indicates that the recently announced investigation of the automobile industry is based on this same emerging policy (*Wall Street Journal; New York Times*, p. 1; *Chicago Tribune*, sec. 4, p. 9).

facts of this case may serve to illustrate the "wonderland" philosophy associated with this type of antitrust policy.

In June 1969 Rufus E. Wilson, then chief of the Division of General Trade Restraints at the FTC, suggested in an internal memorandum that an RTE case be instituted on the basis that the industry was a "non-competitive" business "with a three-firm market share of 83%, with entry virtually barricaded by these three firms . . ." (p. 64). He referred to the "controlling oligopoly" as including Kellogg, General Mills, General Foods, but not Quaker Oats.

In view of that background, the naming of Quaker Oats as a respondent, along with the top three firms in the business, came as a surprise. Facts adduced in the trial have not cleared up the confusion. These facts show that Quaker Oats's share of sales has never exceeded 10% of the business and that for twenty-six years preceding 1970 Quaker Oats's average share of the RTE business was 4%, compared to the aggregate share of 82% enjoyed by the three largest firms. For thirty-one of the thirty-five years preceding the 1972 complaint, Quaker Oats was not even among the top four firms. In fact, Quaker Oats only achieved fourth position in 1968, moving from sixth position where its share of the business for years had been in the magnitude of 2% to 4%. Interestingly, Nabisco, which was not named a respondent, averaged 9% of the business from 1937 to 1970 compared to Quaker Oats's 3.8%.

While we may never learn precisely what the FTC hoped to gain by involving Quaker Oats, it seems apparent that Quaker Oats was included because of successful competition against the rest of the industry in the mid-1960s, since before then its share had been only in the 2% to 3% range. Maybe Quaker Oats is being penalized for competing vigorously with the three industry leaders, moving from a modest RTE business to the fourth-ranking position in the industry. Is the FTC now saying that internal growth by a small competitor to a fourth-place position warrants suit? Is that an unbending, bureaucratic dedication to a four-firm concentration ratio? If so, there is clearly a point where a company should stop competing because of the new risk that a government bureaucracy may decide that success has made it part of a "shared monopoly."

The remedies the FTC seeks from Quaker Oats are limited and contradictory to the basic charges of the complaint. It wants to prohibit Quaker Oats from making any acquisitions in the RTE cereal area for the next twenty years. Quaker Oats has not acquired a cereal business in the last fifty years and has no present plans of doing so.

The only other relief requested from Quaker Oats is the prohibition of its shelf-space programs designed to assist retail grocers in managing displays of RTE cereal in their stores. But the thrust of the complaint on this subject is that Quaker Oats did not push its shelf-space program hard enough in competition with the program offered by Kellogg. The FTC staff would, therefore, ban that which the complaint claims Quaker should have promoted aggressively. This is contradictory.

Much more is sought from the three industry leaders (Kellogg, General Mills, and General Foods), including a sweeping restructuring of their businesses, extensive trademark licensing, and a redistribution of some top-selling brands. The FTC staff wants three new companies spun out of Kellogg, asking that Kellogg give up its Rice Krispies and Special K brands along with manufacturing facilities and other unnamed labels to get the new companies started. General Mills would have to spin off one new company, giving it a plant and the Wheaties brand, while General Foods would also have to spin off one new company and give it a brand as yet unspecified.

The foremost pressure on federal officials to take an anti-big business stand and bring this type of case is to be found in an overly simplistic ideal called "atomistic competition." Since the late nineteenth century, orators in the political arena have proclaimed over and over that the strongest economy is one involving many small business units operating in a purely competitive marketplace (U.S. Congress, Senate 1913). This belief has permeated our thinking as a principle of the first order, becoming a political and social ideal. But the principle is, as many leading economists have noted, self-deceptive, because "this standard has little or no relation to competition as it exists in the real world" (Backman, p. 18). Competition so conceived has probably never existed in any economy and in fact could not exist. A well-intentioned minority in the academic community had embraced that self-deceptive illusion as the cornerstone of a move to fragment American industry. This illusion built up steam with the claims of de-

pression economists that concentrated industries were extracting supracompetitive profits (Bain). It was encased in a shiny veneer in the 1960s by industrial organization economists who claimed that industry performance is dictated by industry structure (Scherer). Thus, the apparent solution looked simple—atomize an industry and better performance will flow.

In that connection, it is appropriate to repeat Harry Truman's belief that "If you laid all the economists in the U.S. in a straight line, they'd point in all directions" (*Give 'Em Hell, Harry!*). The truth is that the structural view is not fully established, even in industrial organization economics (Goldschmid, Mann, and Weston). Unfortunately, "trust-busting" claims receive prominence, and informed explanations to the contrary are often ignored. Consequently, a theory, unsupported by empirical evidence and still being hotly debated among economists, has been adopted by the FTC as the basis of a radical change in antitrust policy.

None of the four major U.S. antitrust statutes decrees that an industry may be dismantled solely because some arbitrary, aggregate level of concentration is reached. This past June, Thomas Kauper, recently assistant U.S. Attorney General in charge of the Antitrust Division, stated that he did not believe that Congress had yet delegated this role ("Antitrust Division Experience etc."). The Justice Department has dropped a "shared monopoly" case against tire manufacturers (*Antitrust and Trade Reg. Rep.* 1976b, p. A-2). Nevertheless, the FTC is assuming a regulatory role similar to that of the Interstate Commerce Commission (ICC), in which it would judge the structure and performance of an industry as if it were a public utility[4] and then reorganize and regulate the industry in order to improve its performance. It is doing so despite congressional deliberations during which there was expressed a total opposition to the establishment of any trade commission that would be authorized to regulate industry generally as if it were a public utility (*Congressional Record,* p. 11089; U.S. Congress, Senate 1914a).

Current congressional activity demonstrates that Congress does not feel it has delegated such authority to the FTC. If the FTC has the power to restructure industries under existing laws, why are members of Congress presently debating the merits of anticoncentration bills to accomplish this very objective? Very recent examples are the Antitrust Improvement Act and Indiana Senator Birch Bayh's bill to break up vertical integration in the country's eighteen largest oil companies by dividing them into separate firms engaging only in production, refining, pipelines, or marketing (U.S. Congress, Senate 1976b; *Antitrust and Trade Reg. Rep.* 1976a, p. A-1). If Congress believed that federal officials already possessed this power, why bother?

In our view, the FTC is being goaded into continuing the pursuit of these doubtful horizons by a proliferation of the works of popular writers who characterize the profit-maximizing goal of business as cold hearted. Robbins, in his book *The American Food Scandal,* charged the four largest cereal producers with "profiteering" and the food industry, in general, with lying to the American people about the true price and quality relationship of their food. Speaking for Quaker Oats, these charges are false. The point is, however, that these books have a strong, immediate, political impact, even when inaccurate. Through emotional appeals, they cause fear and confusion. This leads to demands for someone to act. Federal officials react under such pressure and are so doing despite the consequences.

Before this process carves the new policy in stone, we sincerely hope that someone in a position to be heard will cry out with the truth that federal reorganization of industry is necessarily based on a false assumption. That assumption is that nonelected, transitory government officials have the wisdom, despite a general lack of business experience, to more properly structure an industry than the vast combination of economic forces bearing on the market.

The public should be informed that the United States is, by this policy, moving into a new era of central economic planning. Frightening questions arise. Who in the federal government will fill this god-like role of reorganization? Who will determine which firms deserve what share of each industry after deconcentration? If after reorganization some firms, through competition, enlarge their market shares, will another round of reorganization be required, and, if so, how often?

Have federal bureaucracies previously demonstrated such high competence and skill in

[4] For example, individual firm rates of return on capital employed will be acceptable to the regulators only if they compare favorably with the average rate of return of all manufacturing firms in the United States.

coordinating lesser tasks that they deserve faith with such a monumental responsibility and undertaking? Were people satisfied with their performance during price controls? Did the effects of the Russian wheat deal meet with their approval? Have they been impressed with regulated industries such as railroads controlled by the ICC? Has the postal service been up to their expectations? Have they been impressed with the government's management of our social security fund? Since bureaucratic rules may often be perpetuated to insure job security for the regulators themselves, can we be sure that they are a tolerable substitute for the impartial laws of supply and demand?

For business people, the best indicator of growth of the federal government is the number of new regulations that continually pour out of Washington. Before they can become official, all regulations must be published in the *Federal Register*. When it was first published in 1936, the *Register* had 2,411 pages. By 1974, it had grown to 45,422 pages and last year grew to an astronomical 64,000 pages—a growth of 42% from the previous year. One source likened the massive document to the most monumental book since Gutenberg's *Bible*! It is estimated that each American family pays $2,000 per year (at least one year's supply of groceries) to support this and other aspects of the federal bureaucracy (Sites).

This movement to fragmentize and sterilize domestic firms comes at an odd moment in our economic history. With the passing of the stable international economic system established at the end of World War II, so passed America's ability to remain isolated. Americans cannot afford to be overly protective of economic ideals other than those capable of satisfactory performance in both domestic and international marketplaces.

Given the worldwide, intensive competition for scarce resources, "bigness" in American business may finally be coming into an age when it may, by necessity, be "goodness" in critical economic areas. The federal government, however, has limited its economic focus to domestic market protection via its emerging antitrust policy, with seemingly little concern for the international implications.

The four laws that make up our national economic antitrust policy were framed and passed when development of the national marketplace greatly overshadowed international trade in economic importance. The periods surrounding 1890, 1914, and 1936 were times of political isolationism as well as strong grass-roots discontent with domestic economic conditions. Rather than now using these laws to dismantle our business system, it seems more appropriate to consider whether these acts remain valid in the present era when international economic considerations must rank equally with domestic priorities in order to assure that the United States retain its competitive position in world markets? Shouldn't we be looking to secure entrepreneurial opportunity within the context of a strong, private enterprise system rather than embark on a project of destroying our business structure in favor of a giant bureaucracy?

Concentration of business in the United States is lower than in other major countries in the world (Whitney). In the Soviet Union, concentration is a fundamental principle of that nation's centrally planned economy. Thus, in terms of international trade, the strokes of our antitrust law brush may be painting us into a very tight corner.

Additionally, we are curious as to how the regulators will stimulate the innovation required to discover substitutes for dwindling supplies of necessary resources, improve productivity, and increase consumer satisfaction. Structural remedies, as sought by the FTC in the RTE cereal case, could effectively stagnate a target industry. Innovation normally flows from experimentation and risk taking, spurred on by the profit motive. Whether firms will invest in research and development and take risks to produce major innovations is an open question if, upon success in the marketplace, they will be told to divest the successful assets or license trademarks, royalty free, so that others may capitalize on their hard-won goodwill and success.

It was alarming to learn that the cereal business was selected as a test case because it was viewed as having less political clout than others ("Antitrust: Snap, Crackle and Pop"). This implies a desire by some regulators to quietly establish this controversial policy without risking political and public debate. The real problem with such a low profile is that it masks an attempt to withhold freedom of choice from American consumers. It seems some federal regulators have concluded that consumers buy too many varieties of RTE cereals. The trademark-licensing remedy in the cereal case is designed to discourage development of further varieties. Yet, Americans have jealously guarded their constitutionally protected freedom of choice in other

areas. Why would we surrender this freedom to government officials in deciding what food products we will consume (so long as there is no health or safety hazard)? How long will our freedom of choice last elsewhere if we let federal officials assume they have the right to absorb it in this instance? An individual's economic, social, and political choices are interwoven and not easily separable. Restriction of one must have substantial effects on the others. How safe are our freedoms of speech and press when the economic forum, of which they are parts, is to become the realm of the government regulator?

In Orwell's prophetic work *1984*, he portrayed a society where reality was the opposite of the image painted by the government. His Ministry of Love controlled the minds of citizens through terrifying uses of fear. Similar contradictions are present in the federal government's move against our private market structures. It declares that concentration in business must be reduced through concentrated, centralized government planning. If we accept this panacea, we may learn to our detriment the truth of Orwell's view that the inherent nature of all highly centralized governmental organizations is to suppress that which they profess to protect.

Many agree with the editors of *Fortune* magazine who recently warned that the "real danger to American liberty is not that it will be trampled by iron heels but that it will be slowly buried in a dust of bureaucratic oppression. . . . We will have to insist, as a start, that legislators be much more cautious about authorizing government agencies to do things—and much more diligent about specifying what they may *not* do" (p. 118).

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An Evaluation of the Economic Basis for Antitrust Policy in the Food Industry

Bruce W. Marion and Thomas L. Sporleder

Distrust for concentration of economic power pervades U.S. antitrust history, stemming as much from concern for protection of democratic institutions, equality of opportunity, and preservation of citizen control as from concern about economic performance.

The goals and rationale of antitrust are only partially revealed by the language of antitrust laws. Although these laws emphasize economic criteria (e.g., to substantially lessen competition), the history of their enactment and enforcement reveals the strong influence of political and social goals as well as evolving legal and economic theories. Dewey may be right in contending that antitrust policy in this country has been aimed most consistently at limiting the power and growth of big business in order to encourage a more equitable distribution of power in society.[1]

This paper concentrates on the economic underpinning of U.S. antitrust laws. We recognize, however, that economic concepts and evidence are not alone in providing the basis for antitrust policy and that a restricted treatment ignores important noneconomic goals and concepts.

Economic Basis for Antitrust

Industrial organization theory, as set forth by Bain, posits that industry structure determines (or strongly influences) the conduct or behavior of firms within an industry and that firm conduct determines (or strongly influences) their collective performance. In recent years, Bain's model has become the main economic paradigm for interpreting and enforcing U.S. antitrust laws. The many attempts to verify or refute Bain's model since 1960 have added much to the theoretical richness and practical understanding of imperfectly competitive markets. Although varying greatly in focus and rigor, much of this research has examined relationships between the structure of markets (especially market concentration) and their performance (especially profits). Given the critical role accorded Bainsian theories, a brief critique of methodology and empirical findings is warranted.

Methodological Concerns

A survey of methodology in existing industrial organization studies is beyond the scope of this paper. Several such surveys are available (Weiss 1971, Vernon). However, a few topics of importance to the food industry receive comment.

Definitions, data, and methodology are each essential to theory verification. Each represents unique potential for invalid theory verification. Reverence for precise definition is innate to theory. Concepts such as market, firm, and industry reside as part of rather precisely defined theoretical constructs of the structure-conduct-performance (S-C-P) model. Although theory may be eugenic, secondary data coincident with relevant market areas for a neatly defined single product firm or industry may be impossible to obtain. Increased propensity toward diversification and conglomeration aggravates the problem of obtaining theoretically relevant data.

Access and cost constrain many verification efforts from utilizing primary data that are more consistent with theoretical definitions than existing secondary data. Of special rele-

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The order of the authors is not intended to reflect relative contributions.

[1] Kaysen and Turner suggest four possible aims of antitrust policy: (*a*) the attainment of desirable economic performance with respect to efficient use of resources, progress, stability of output and employment, and equitable distribution of income; (*b*) protection of competitive processes by limiting market power; (*c*) enforcing a standard of fair conduct in business; and (*d*) limiting the power and growth of big business and promoting small business to encourage a more equitable distribution of power in society.

vance to the food industry are market area data. Most large grocery chains and food manufacturers operate in multiple markets, whether product or geographic. Secondary data available on major variables, such as concentration, profits, and prices, often lack appropriate levels of disaggregation and/or appropriate time periods.

Adequate quantification of theoretically important variables has continually plagued industrial organization studies. Barriers to entry and product differentiation, as dimensions of market structure, must be estimated largely via surrogate variables, as must the performance dimensions of progressiveness and technical efficiency. In addition, measures of market concentration have largely relied on Bureau of the Census's four- and eight-firm concentration data that have widely recognized definitional problems. Concentration measures also do not distinguish between various institutional arrangements such as retail chains versus affiliated independents or national brand versus private label processors. Plausibly, concentration both within and among such institutional groups is important for determining market-specific industry performance.

Since most industrial organization studies of the food industries rely on cross-section multiple regression models, the ubiquitous question of association versus causality is of continuous concern, particularly in examining certain aspects of the S-C-P model (Asch and Seneca). Regression analysis of food manufacturing companies also have revealed serious problems of heteroskedasticity (Imel and Helmberger, Arnould and Fletcher). Increased diversification of food manufacturers is likely to force more studies to use firms rather than industries as the unit of analysis, thereby making heteroskedasticity a more common problem in the future. Fortunately, methodology is available for dealing with this problem (Imel and Helmberger).

Relatively scant attention has been paid to conduct in the S-C-P approach. This undoubtedly relates the methodological difficulties inherent in quantifying conduct. Some recent advances, however, have involved utilization of the theory of investment under uncertainty and more generally probabilistic approaches (Weston). Pricing behavior analyzed in a probabilistic framework could add fresh insights to market conduct-performance relationships.

In an enumeration of methodological issues relevant to antitrust, measurement of welfare loss must be included. One interindustry comparison of welfare loss indicated severe concentration of the industry source of the welfare cost of monopoly. However, the percentage of the total welfare loss attributed to food and food-related manufacturing industries was relatively small (Siegfried and Tiemann, p. 197). Interindustry estimates of welfare loss are of obvious importance for prioritizing antitrust activities in the economy but are subject to attack on methodological grounds, such as the assumption of constant own-price elasticity of demand across industries or the failure to consider monopoly effects on costs as well as prices. Research is needed on the welfare loss question in agriculture and the food industry in general.

The data and methodology problems in industrial organization research are substantial and should not be understated. Still, these problems have not prevented a large number of valid research efforts from being conducted. The problems do increase the difficulty of empirical efforts and account for some of the variability in results.

Empirical Evidence

The strongest and most consistent empirical relationships have been found between market concentration and profits (allocative efficiency). This relationship has been extensively tested. Weiss, after carefully reviewing nearly fifty studies, concluded: "In general, the data have confirmed the relationship predicted by theory, even though the data are very imperfect and almost certainly biased toward a zero relationship. . . . Altogether, there is still plenty of reason to believe on both theoretical and empirical grounds that high concentration facilitates tacit or explicit collusion" (1974, pp. 231–32).

Relationships between allocative efficiency and structural elements of entry barriers and product differentiation also have received considerable analysis. In general, industries with high barriers to entry and/or high advertising expenditures (proxy for product differentiation) tend to have significantly higher profit levels than industries characterized by low or moderate entry barriers and/or advertising (Scherer, Mann). The direction of causality and theoretical rationale for the profit-

advertising relationship are subject to some debate, however.

Relationships between market structure and other dimensions of market performance are less clear. Although it is often assumed that concentrated markets are technically more efficient, the large size of most U.S. markets allows for firms that are large in absolute terms without high concentration. Bain concludes from his analysis that the main impact of market structure is probably on performance dimensions other than technical efficiency.

However, empirical studies of scale economies have concentrated on production economies, virtually ignoring economies that may exist in procurement, finance, marketing, and planning. Scale advantages in marketing (advertising, physical distribution, and new product development) likely account for the substantial increase in concentration in consumer goods manufacturing industries, while concentration in producer goods manufacturing industries has remained relatively stable in recent years (Mueller and Hamm).

Progressiveness in relation to market structure has been extensively examined, albeit with relatively weak data. Scherer concludes that neither very low nor very high concentration is conducive to progressiveness, that a "subtle blend of competition and monopoly" (p. 378) with modest entry barriers is needed for rapid technical progress.

The foregoing highlights the empirical efforts that have particular relevance to antitrust. Some important topics have been bypassed for lack of compelling evidence.[2] Where do we come out on balance? Is the S-C-P model verified? We believe the weight of evidence calls for a qualified yes. Certainly, a thoughtful person would find it difficult to review the myriad of studies and contend that market structure and performance are unrelated. Although the direction and strength of the relationship between certain structural and performance elements is still rather murky, we accept that market structure does in fact influence several aspects of market performance.

While this conclusion may be open to challenge, an equally interesting question is whether Bain's model is relevant for analysis of current antitrust issues in the food industries. To examine the relevance of the S-C-P model, identification of critical antitrust issues is necessary.

Antitrust Issues in the Food Industry

Many food industry antitrust issues are germane issues to the general economy as well. The most critical issues are briefly outlined.

(*a*) What structure of food retailing and food manufacturing markets will generate the optimum balance of operational efficiency, allocative efficiency, and progressiveness, and what are appropriate policies to move industries toward the ideal structure? The interrelationships of market structure, progressiveness, and economies of scale are critical to this issue and are not well defined. Policies for dealing with established positions of excessive monopoly power must also be determined.

(*b*) What is the extent and effect of various types of conglomeration in the food industry? For example, what is the effect of multimarket grocery chains or conglomerate food manufacturers on competitive behavior and small firm competitors?

(*c*) What is the extent and influence of various vertical linkages and arrangements in the food system, including vertical integration, contractual and tying arrangements, exclusive dealing and situations involving monopsonistic procurement power?

(*d*) How adequate are the information and communication systems in the food system? For consumers to be sovereign, they must be informed. Information, rightfully a dimension of market structure, has for too long been ignored via assumptions of perfect (or at least adequate) knowledge. Since much information flows vertically, vertical arrangements may have an important bearing on the status of information.

(*e*) What is the power and effect of producer cooperatives and labor unions (both presently exempt from antitrust laws)? What are the propensities of these organizations toward concentration, and what are the performance implications?

(*f*) What are the forces operating in the food industry that generate structural change or stability? What changes are likely to evolve under a laissez-faire public policy?

The Bain model and empirical evidence

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[2] The relationship between market structure and prices, wages, and employment has received considerable but spasmodic attention over the years. Evidence on this important topic is still somewhat cloudy, although the experiences of the Nixon administration support the administered inflation theory. There is also a growing amount of empirical work on the sociopolitical effects of monopoly power and large firms.

provide a useful framework within which to examine the above issues, but they are not in and of themselves adequate to guide public policies on any of these issues. At present, the S-C-P model provides the most guidance on issue (*a*) and the least on issues (*b*) and (*c*). Empirical research has shed valuable light on the critical levels of concentration, product differentiation, and entry barriers. This research has provided the economic basis for merger guidelines and enforcement action, for proposed legislation calling for industry restructuring, for proposals to limit advertising, and for the selection of key cases such as the shared monopoly case against four cereal companies. With some modifications, the model lends itself to examining aspects of the other issues. However, the lack of empirical research on these subjects results in few policy guidelines.

In examining the strengths and limits of the S-C-P model for addressing current antitrust issues, some limits of the model can be attributed to the lack of data or empirical efforts needed to verify or refute, some to the failure of researchers to include important structure, conduct, or performance variables, and some to limitations in the construct of the model itself. For example, the model does not consider the influence of alternative vertical linkages on subsector performance. In addition, by excluding business conglomeration and multinational characteristics as structural variables, the model has limited the research focus of many industrial organization economists (Mueller). The paucity of empirical analysis of the causes and consequences of various types of market conduct limits model usefulness for addressing antitrust issues such as price discrimination, tying arrangements, and predation.

The model clearly "fits" best in addressing the structure and performance of industries composed of relatively specialized firms and in which product or process technological change is relatively unimportant. With increasing diversification in the food industries, this is less and less the case. Modification and adaptation of the basic Bainsian model are called for in order to address some of the current issues. Also, analyses increasingly must be done using individual company data similar to the Federal Trade Commission (FTC) "Kelly Report" and are highly dependent upon data such as the FTC line of business reports.

Alternative Economic Bases for Antitrust Policy

The S-C-P triad is based on static deterministic microeconomic theory. Within this context "at least twenty-one concepts of the firm" have emerged that in some way change the objective of maximizing money profits (Malchup, p. 26). Although many alternatives have sought more realistic and/or more dynamic concepts of economic organization, few distinct and definable paradigms that are empirically verifiable have emerged.[3] Only two alternatives to the conventional profit preference function have emerged in terms of marginal analysis that have been recognized widely. This section briefly reviews each and the relatively new organization failures paradigm.

Alternative Preference Functions

When ownership and management are separate, Williamson (1964) proposes a management discretion theory where management maximizes a utility function $U = U(E, I, S)$, subject to $\pi \geq \pi_0$, where E is expenditure on staff (monetary compensation of management and the quantity and quality of their staff), I is investment expenditure that management controls in a discretionary manner, S is management slack (quantity and quality of nonmonetary compensation received by management, which is strictly in excess of amounts needed for the firm's operation), and π_0 is the minimum profits necessary to ensure survival of existing management. Neither I nor S is assumed to influence marginal cost, but they are assumed to contain sales promotion expense that may influence marginal revenue by shifting demand. Optimality is defined by $\partial R/\partial Q = \partial C/\partial Q$ and $\partial R/\partial E < 1$. Total revenue is denoted by R, total cost by C, and output rate by Q. Equilibrium output rate may exceed conventional profit preference function equilibrium and X-inefficiency will exist.

Baumol has suggested an alternative preference function that involves maximization of dollar sales subject to a minimum profit constraint. Profit maximization is rejected because this preference function cannot explain

[3] The many writings on workable competition and dynamic innovative competition represent alternative rationale for antitrust to Bain's model. This body of thought has supported the "rule of reason" approach to antitrust, which has spasmodically been in favor with the antitrust agencies. Clark, Sosnick, and Schumpeter have provided some of the fundamental concepts in this general area. It is such a diffuse body of thought we have chosen not to present it as an alternative framework.

some aspects of oligopoly behavior such as the tendency to raise price to cover increases in fixed costs. Rather than $MC = MR$, strict sales maximization would require $MR = 0$. Hence, some output would be sold where $MC > MR$; however, this is limited by a minimum profit constraint (Kafoglis, pp. 584–85).

Management will maximize a revenue function $R = R(Q, A)$, subject to $\pi \geq \pi_0$, where all symbols are as before and A represents expenditures on sales promotion and advertising. To maximize R requires $\partial Z/\partial Q \leq 0$, $\partial Z/\partial A \leq 0$, and $\partial Z/\partial\lambda \geq 0$ from the Lagrangian function $Z(Q, A, \lambda) = R - \lambda\ (\pi - \pi_0)$.

Revenue preference function equilibrium occurs at lower price and greater output than managerial preference function equilibrium. Also, revenue maximization is not necessarily consistent with preference for output or physical size of firm. Price and output comparisons among profit, revenue, and managerial preference function firms are difficult since various assumptions can be made regarding revenue-cost relationships. Also, comparisons of price-output are sensitive to cases of increasing, decreasing, and constant costs (Kafogolis, p. 585–86).

Organization Failures and Hierarchies

Another approach to economic organization, loosely referred to here as organization failures and hierarchies, stems mostly from Williamson's revival of the transaction as the principal unit of microeconomic analysis (1975).[4] The approach takes firms and markets as alternative methods for completing a related set of transactions and considers the relative efficiency of each method. Costs of contracting across markets may be explained by the interaction of environmental and human factors. For example, uncertainty from the environmental sphere and bounded rationality from the human sphere may interact so that "it is very costly or impossible to identify future contingencies and specify, *ex ante*, appropriate adaptations thereto," which results in internal organization replacing long-term contracts (1975, p. 9).

Organizational failure refers to both market and internal organizational failure.[5] Hierarchies refers to the subordinative association of work groups that represent nonmarket alternatives for completing transactions. Thus, the core of the Williamson analysis is transactional in nature and focuses on intrafirm organization as well as interfirm interaction for possible explanation of observed oligopoly behavior.

Conclusions and Implications

At this point in time, Bain's S-C-P model is the only well-developed, and at least partially operational, theory on which to base antitrust policy. However, this model provides limited guidance on several important antitrust issues and, because of data and methodology problems, may never be adequately verified.

Empirical results generated from the S-C-P framework provide rather persuasive evidence for limiting horizontal concentration of industries. Whereas moderate levels of concentration may often be beneficial, high levels appear to be seldom justified. This provides solid economic rationale for dealing with horizontal mergers. Economic rationale for dealing with price conspiracies is likewise strong. The economic underpinning is relatively undeveloped, however, for antitrust policies concerning predation, price discrimination, vertical mergers, and pure conglomerate mergers. Antitrust laws bearing on the latter topics also are heavily dependent upon the perceived purpose of antitrust, that is, the extent to which dispersion of economic power and preservation of small firms is a high priority of antitrust policy.

The alternative paradigms reviewed may in time prove useful in guiding antitrust policy. At present, however, they are largely undeveloped and untested. Their potential merit is, therefore, difficult to judge.

The greater realism of models with alternative preference functions is appealing, especially since the rigor of marginal analysis can be retained with these alternatives. Although neither of these models has been verified, we suspect they contain at least a "germ of truth." However, logic and empirical evidence suggests that alternative objectives do not replace or submerge the objectives to increase (if not maximize) profits. The consis-

[4] "Revival" because of the Commons antecedent and the antecedent of institutionalists in general. Also, an extension of transaction as the principal unit of analysis has evolved, divergent from Williamson (1975), that examines structure of property rights and is primarily associated with writings of Alchian and Demsetz.

[5] Market failure refers to transaction costs which can be reduced by substituting internal organization for market exchange (see Williamson 1975 for explanation).

tent positive relationship found between concentration and profits indicates that, whether or not profits are maximized, when the market environment allows an increase in profits, management is quick to oblige. Thus, the basic S-C-P relationship still appears valid although alternative preference functions may suggest a more complete set of causal factors affecting industry conduct and performance.

In both of the models reviewed, performance is largely determined by management discretion, not by the compelling force of the market. They would, therefore, seem to apply in those market situations where some degree of market power and management discretion exists. These models would provide a vague and transitory basis for antitrust policy and would support a "rule of reason" approach to antitrust. Experience suggests that this would result in little enforcement.

The organizational failures framework holds particular potential for dealing with vertical linkages and arrangements. Transactions play a major role in the organizational failures framework that attempts to merge concepts from organization theory and economic theory. This somewhat different view of the world, although still lacking a comprehensive taxonomy or analytical framework, should shed fresh light on vertical and possibly conglomerate organizational phenomena. This framework emphasizes the logic or rationale for creating or changing certain organizational designs. However, it is relatively mute on the performance consequences of alternative organization arrangements.

Perhaps the greatest contribution of the alternative paradigms at present is in offering a different set of glasses through which to see the world and hence suggesting alternative hypotheses to be tested. For example, the uneconomically large number of retail stores in a local market can be interpreted as entry barriers erected by established firms to maximize long-run profits or as an effort to maximize sales or consumer convenience to the detriment of both short-run and long-run profits. Similarly, conglomeration can be viewed from a S-C-P perspective in which reciprocity, cross-subsidization, and mutual forebearance are examined, or from the organizational failures viewpoint that contends that capital market failures may be a leading cause for conglomeration since through internal resource reallocation the firm can avoid "nontrivial" transaction costs. However, until the alternative paradigms are more fully developed and at least partially verified, they are of little value as a basis for antitrust.

The economic underpinning for parts of antitrust is rather solid, for other parts rather fragile. Additional empirical analysis is particularly needed in certain areas to test alternative theories and to lead to more complete theories. At this point, many industrial organization questions are still empirical questions. While this can be interpreted as a pessimistic assessment, it is probably no less so than an assessment of the economic underpinning for most areas of public policy. Although what we know about industrial performance may be an "island protruding from a sea of ignorance," at least we have that island.

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Technical Change, Labor Use, and Small Farmer Development: Evidence from Sierra Leone

Dunstan S. C. Spencer and Derek Byerlee

In large areas of Africa where land-labor ratios are high and use of capital is minimal (usually less than $10 per farm annually), labor is the dominant factor of production. Effective use of labor is then a key element in any program to increase output and incomes among small farmers. Following Hayami and Ruttan, technical change appropriate to these factor endowments would involve adoption of labor-saving technology for peak season operations to raise labor productivity. When the labor bottleneck occurs at planting time as is common in tropical Africa, this translates into mechanization of planting operations, particularly land preparation to enable expanded acreage. However, because labor constraints are only seasonal, conventional land-saving technologies may also be appropriate. If planting labor is the bottleneck, biological-chemical technologies that increase yields per acre and hence increase weeding and harvesting labor but leave planting labor unchanged will in fact be labor saving with respect to labor at the peak season. It is not uncommon to observe both mechanical and biological-chemical technologies being adopted side by side in high land-labor ratio areas in Africa.

These interrelationships between technical change and demand for labor must also be examined within the context of available labor supply. Where there is no class of landless laborers because of the land surplus situation, labor supply to agriculture depends primarily on the time input and allocation of family members, particularly at the peak season. Competition with nonfarm activities has been shown to be one important component of labor supply to farming (Norman, Byerlee and Eicher). Recently, there has also been interest in the role of female labor supply in both traditional and improved farming systems.

Despite the obvious importance of these labor supply and demand relationships to small farmer development, there are relatively few detailed studies of labor utilization in traditional African agriculture and almost none that examine labor use under improved technologies. The objectives of this paper are then to briefly highlight some findings based on a detailed farm survey, with respect to labor use in two contrasting situations—one employing mechanical cultivation and the other improved biological-chemical technology—in rice production in Sierra Leone.

Specifically, we shall first examine labor use from the demand side, noting the impact of the different technological packages on resource combination and returns to labor. We then examine labor use from the supply side by analyzing the impact of technical change on household family labor inputs and the differentiation of labor use by sex.

Data Sources

Data reported in this paper were obtained as part of a nationwide farm management survey

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conducted during 1974–75 of 500 rural households in twenty-four enumeration sites in Sierra Leone, chosen on a stratified random basis. Data were obtained by locating enumerators at each survey site and interviewing farmers twice weekly over a twelve-month period (Spencer and Byerlee). In this paper we discuss data from only two survey areas. The first area is situated in the center of the Boliland area where rice is grown in infertile swamp grasslands. Extensive mechanical cultivation is practiced in the area through a government hire tractor scheme that charges a subsidized price for tractor services.[1] The second study area is located in the Moa Basin region in an area served by an Integrated Agricultural Development Project (IADP) established in late 1973 with major emphasis on improved biological-chemical technology for production of inland swamp rice. Each farmer participating in the project receives credit, improved seed, fertilizer, and tools, as well as extension advice on constructing water control facilities. No mechanical cultivation is practiced in the area.

Technical Change and Labor Use in Rice Production

Labor inputs for rice production using varying technologies are shown in table 1. In the IADP area, farmers previously grew upland rice using traditional bush fallow cultivation where a new piece of land is cleared each year. Some farmers also grew swamp rice under traditional methods where land is continuously cultivated. These two production systems are used as benchmarks for the "without" project situation to be compared with the improved seed, fertilizer, and water control methods used by farmers in the project. In the Bolilands labor use under hand cultivation is compared with mechanical cultivation. It should be noted that we are comparing enterprises, not farms. In the IADP area farmers often produce traditional upland rice in combination with traditional swamp rice, while farmers in the IADP for the first year usually continue to produce upland rice in combination with improved swamp rice production. Farmers in this area also produce tree crops, particularly cocoa, coffee, and oil palm. In the Bolilands over half of the sample practiced both hand and mechanical cultivation of rice, but few other crops were produced.

Labor inputs are computed in person-hour equivalents assuming that the ratio of wage rates for hired men, women, and children accurately reflects the marginal rate of substitution between labor of different types. In the IADP area labor inputs per acre have increased substantially as a result of participation in the project (significant at the 1% level). The increased labor per acre is due to improved land preparation and a larger harvest.[2]

In the Bolilands labor inputs per acre declined by 40% as farmers substitute capital for labor in land preparation activities. To further understand these production relationships, a constant elasticity of substitution production function was fitted to farm data for the Bolilands with the form

$$\ln Y = V/P\,[\ln (S_1 L^P + S_2 K^P)],$$

[1] There is also some variation in biological technology in the Boliland area with respect to the planting procedures—broadcasting or transplanting—and use of fertilizer.

[2] Weeding is not an important activity in swamp rice production in either of the two study areas.

Table 1. Labor Inputs and Yields in Rice Production under Differing Technologies in Sierra Leone, 1974–75

	Labor Input per Acre[a] (Person Hours/Year)			Yield per Acre (Pounds/Acre)
	Family	Hired	Total	
IADP area				
Traditional upland	884	60	953	798
Traditional swamp	697	39	736	1,260
Improved swamp[b]	1,125	256	1,393	1,734
Bolilands				
Hand cultivation	270	47	317	858
Mechanical cultivation	153	40	193	1,008

[a] Person-hour equivalents computed by applying weights of 1.0, 0.75, and 0.5 to men, women, and child labor, respectively, in the IADP area and weights of 1.0, 1.0, and 0.5 to men, women, and child labor in the Boliland area. Weights reflect relative wage rates in those areas as discussed in Spencer and Byerlee.

[b] IADP package of fertilizer, seed, and water control.

where Y is total value added in rice production, L is input of labor (in person-hours), K is payment for the tractor hire services, V is the returns to scale parameter, P is the substitution parameter such that the elasticity of substitution is $1/(1 - P)$, and S_1 and S_2 are distribution parameters. The value of P estimated was 1.0 with standard error 0.82, indicating a high elasticity of substitution.[3]

Although land is not included in this equation, the returns to scale denoted by V is 0.99, indicating constant returns to scale on labor and capital services. This provides evidence that land is not a limiting factor. Because land is relatively abundant in this area, farmers expand acreage with mechanical cultivation. The average size farm for those farmers with only hand cultivation was 8.4 acres, compared with 12.7 acres for farmers using mostly mechanical cultivation. These results indicate that substantial flexibility exists to substitute capital for labor in the Bolilands. However, it is important that this substitution enables an expanded acreage to be cultivated, and, although labor-saving technology is employed, it is not necessarily labor displacing.

Yields of rice per acre are also presented in table 1. In the IADP area yields per acre of improved swamp rice are more than double yields on traditional upland rice and 37% higher than under traditional swamp rice. In the Bolilands yields per acre are slightly higher on mechanically cultivated farms, but regression analysis of yield data indicated that this was due to higher fertilizer applications on mechanically cultivated fields and not due to any effect of mechanization per se.[4]

Enterprise budgets for each farming system are constructed in table 2. In the IADP area, returns per acre are increased on improved swamp rice farms compared with traditional systems. However, returns per man-hour of labor input are lower on improved swamp rice compared with traditional swamp rice production, although 50% higher than on upland rice production. Adoption of the IADP package to improve swamp rice has resulted in

[3] Equation estimated directly through nonlinear maximum likelihood regression approach following Ramsey and Zarembka. R^2 for the estimation was 0.73. This function was chosen because, unlike the Cobb-Douglas function, it allows the elasticity of substitution to range from zero to infinity and can thus better reflect the extent to which factors can be substituted for one another.

[4] The function fitted was $Ya = 7.40 + \underset{[0.07]}{0.15}\,Fa + \underset{[0.006]}{0.014}\,La$, where Ya is yield per acre (bushels), Fa is fertilizer per acre (pounds), and La is labor per acre (hours). Standard errors are bracketed, and the R^2 is 0.50. A variable representing method of ploughing (hand or mechanical) had no significant effect. However, mechanical farms use 60 pounds of fertilizer per acre compared with 37 pounds per acre on hand cultivation.

Table 2. Enterprise Budgets for Different Systems of Rice Production in Sierra Leone, 1974–75

	IADP Area			Bolilands	
	Traditional Upland	Traditional Swamp	Improved Swamp[f]	Hand Cultivation	Mechanical Cultivation
	Average/Acre				
Output-value (Le)[a]	67.0	105.0	144.0	61.4	72.1
Variable costs (Le)					
Land payment	0	0	0.7	0.3	2.1
Seed	5.3	4.4	5.1	4.5	3.8
Fertilizer	0	0	1.5	0.8	1.2
Mechanical service	0	0	0	0	6.8
Hired labor[b]	6.5	4.7	23.9	3.1	3.1
Others	0	0	2.2	0	0
Total variable cost	11.8	9.1	33.4	8.6	16.9
Interest on total costs[c]	2.3	1.8	6.7	1.7	3.4
Enterprise gross margins[d]					
Per acre	52.6	94.1	103.3	51.1	51.9
Per hour of family labor	0.06	0.13	0.10	0.18	0.34
Gross margins per hour family labor with unsubsidized costs[e]	0.06	0.13	0.09	0.18	0.06

[a] Le 1.00 = $1.10 U.S. in 1974–75.
[b] Valued at wage rate specific to the area.
[c] Assumes 20% opportunity cost.
[d] Output value less variable costs less interest on variable cost.
[e] Assumes fertilizer subsidy of 67% and mechanical ploughing subsidy of 85%.
[f] IADP package of seed, fertilizer, and water control.

increased returns to land, but because of the added labor, returns per unit of labor are lower than under traditional swamp cultivation systems.

In the Bolilands returns per unit of land are virtually the same for both hand and mechanical cultivation. However, returns per unit of labor are substantially higher under mechanical cultivation.[5] Moreover the marginal value product of labor estimated from the constant elasticity of substitution production function fitted above is Le 0.19 per hour—almost identical to average returns to labor on hand cultivated fields. (The Sierra Leone monetary unit, the Leone [Le], was valued at $1.10 U.S. in 1974–75.)

In Sierra Leone mechanical services and fertilizer are both heavily subsidized. To assess the economic returns in both projects, returns to labor were recomputed using unsubsidized prices.[6] For the IADP area, returns are virtually unchanged, but in the Bolilands hand cultivation is now considerably more profitable than mechanical cultivation. In fact, the previously high returns to labor under mechanical cultivation are reduced to a level below that of improved swamp cultivation in the IADP area. The results indicate that neither the biological-chemical technology of the IADP nor the mechanical technology of the Bolilands is particularly successful as measured by returns to the limiting factor—labor. If returns are to be increased in the IADP area, either labor inputs must be reduced or yields increased.[7] In the Bolilands the increase in cultivated area resulting from mechanization has occurred at substantial cost given the current high cost of operating the government tractor hire scheme.

The relationships observed here are consistent with theoretical expectations. The mechanical technology has increased labor productivity, while the biological-chemical technology has increased land productivity. However in each case only one technology among a range of potential alternatives was evaluated. Biological-chemical technologies employing only improved seed and fertilizer but not water control measures may be more appropriate than the IADP package considered here. In fact, elsewhere Spencer has shown that investment in improved seed and fertilizer in upland rice has greater potential for increasing returns to labor than either of the two technologies evaluated here. Likewise, tractor cultivation represents only one form of mechanization. In Ghana, Winch has investigated several technological alternatives for rice production and concluded that a combination of tractor hire for cultivation and improved seed was most profitable, although hand cultivation was not considered as an alternative.

Technological Change and Total Household Labor Use

In assessing the impact of technological change on total family labor use, it is necessary to consider all household production activities, since labor may be shifted between rice production and other crops and between farm and nonfarm activities at different seasons of the year. In addition, it is also important to analyze how the introduction of technological change affects the division of labor by sex. In fact, several writers (e.g., Boserup and Tinker) assert that new agricultural technologies have an adverse effect on women, since they lead to an increase in women's work loads, while the work loads of men are reduced.

The seasonal profile of total hours worked each month by family members in farm and nonfarm work (excluding domestic duties, such as cooking) for the two survey sites are shown in table 3. In the IADP area, households were divided into three groups: nonparticipants or households who had not joined the IADP, households who were participating in the project for the first year, and households who were second-year participants in the project. Boliland households are grouped into households using primarily hand cultivation, households using mixed hand and mechanical cultivation, and households using primarily mechanical cultivation.

Of course, with cross-sectional data, we cannot always be sure that the difference among groups are the result of the technological adoption or the cause of the adoption. In

[5] In fact, part of this difference is the result of higher inputs of fertilizer on mechanical farms. If hand cultivation fields use the same level of fertilizer, returns per man-hour are Le 0.22.

[6] It is estimated that current subsidy levels are 67% for fertilizer and 85% for mechanical services.

[7] Yields of improved rice in the area are below the potential for the area partly because farmers did not follow recommended practices especially in the second year of participation when the level of extension advice was reduced, cultural practices were poor, and the rate of fertilizer was reduced. Also, labor inputs are high partly because farmers are still engaging in land improvement even in the second year of the project.

Table 3. Seasonality of Labor Inputs for Adult Family Members in Sierra Leone Rural Households Using Differing Agricultural Technologies

Type of Household	Sample Size	Month[a] May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	Total Hours for Year[b]
		Average Hours Worked/Adult/Month													
IADP area															
Male															
Nonparticipant	14	67	147	114	141	93	68	67	68	70	81	60	51		1,027
First-year participant	10	187	231	228	268	207	140	124	134	151	131	102	125		2,028
Second-year participant	14	167	162	232	201	137	92	84	66	82	69	95	85		1,472
Female															
Nonparticipant	21	46	140	145	164	114	106	106	54	74	41	18	29		1,037
First-year participant	14	96	145	153	144	116	80	97	80	87	52	19	36		1,105
Second-year participant	15	139	156	143	211	143	89	83	60	60	34	22	28		1.168
Bolilands															
Male															
Hand cultivation	10		125	186	231	199	128	137	204	182	97	56	55	80	1,680
Hand and mechanical cultivation	12		95	184	239	179	93	78	157	160	85	38	25	46	1,379
Mechanical cultivation	14		95	181	215	221	158	120	178	145	57	24	42	52	1,488
Female															
Hand cultivation	7		55	108	160	81	53	39	57	88	54	32	20	22	769
Hand and mechanical cultivation	6		60	133	193	103	86	69	99	119	67	50	25	24	1,028
Mechanical cultivation	20		90	158	214	164	84	75	121	107	59	40	25	32	1,169

[a] Survey from May 1974 to April 1975 in IADP area and June 1974 to May 1975 in Bolilands.
[b] Differences between groups significant at 5% level for males in IADP and for females in Bolilands.

the following comparison among groups observed differences are assumed to be the result of the technological change. Boliland households with and without mechanical cultivation exhibit similar characteristics with respect to age and sex composition of family members. However, in the IADP area heads of nonparticipant households are older than for participant groups, so that a priori we expect their labor inputs to be somewhat lower.

There are definite seasonal peaks in labor use at planting time in June to August and harvest time in December and January and well-defined slack periods—in October and November and in the dry season from February to May. In the peak month, male adults consistently work over 200 hours per month. The one exception is the nonparticipant group in the IADP area with a peak monthly average of 147 hours. However, this in part reflects the heterogeneity of this group with respect to crops, so that the peak month varies from household to household. When this average is computed using the peak month for each household, the male labor input is 190 hours per month.

The high labor input at the peak season is accomplished through working both more days and longer hours per day. For example, in the Bolilands at the peak month of August, male adults worked twenty-eight days at an average of 8.4 hours per day. Moreover, the number of people who did any work in a month changed over the season through the participation of older people and short-term visitors who are (presumably in response to seasonal labor constraints) concentrated at the peak seasons of harvesting and planting. Work is concentrated on farming activities at the peak season. In the Bolilands the percentage of time of male adults spent on nonfarm activities such as blacksmithing, trading, and construction is only 1.6% in the peak months (July to September) compared to 40% in the slack period (March to May). These results strongly underline the magnitude of the labor constraint at the peak season. The maximum number of people are working in agriculture almost every day for long hours each day during this period.

The technologies examined here have had relatively little impact on the "spread" of labor inputs over the year. In every case the peak season occurs at planting (July through September) with a subsidiary peak at harvest (December and January). In the IADP area, first-year participants in the project have less pronounced slack periods partly because they are still producing some traditional upland rice, which has different seasonal labor demands than swamp rice (Spencer and Byerlee). In the Bolilands labor inputs of households with mechanical cultivation are slightly less in the slack period, since this is the time of mechanized land preparation.

The introduction of improved technologies

has a significant impact on the use of household labor by sex. In the IADP project male adults increase their labor inputs by at least 50% when they join the project. In the first year of participation in the project when most land development is undertaken, male adults worked over 2,000 hours per year. In contrast, female labor input is not significantly changed by participation in the IADP project.

In the Bolilands, the effect of mechanical technology on labor use by sex is quite different. The mean hours of work per adult male decrease slightly as mechanical cultivation is substituted for hand cultivation (the difference is not statistically significant even at the 30% level). However, the hours worked increase significantly for female adults, so that in households using primarily mechanical cultivation, females work 50% more than in those using primarily hand cultivation. Also, at the peak season, women in households using mechanical cultivation work the same number of hours in farm activities as men.

The key to these differential effects of varying technologies on male and female labor inputs lies in the sex-specific nature of some farm activities in Sierra Leone. In the Bolilands mechanization almost completely eliminates the land preparation undertaken by men but increases farm size so that there is an increase in the demand for labor for planting and harvesting where women traditionally play an important role. In the IADP area, the substantial land development required in the early years of the project places the burden of the work primarily on men.[8]

This analysis of total work hours for adults shows that the number of hours worked for both men and women nearly always exceeds the 1,000 hours per year noted by Cleave in a review of several African surveys. In most cases, this labor input exceeds 1,200 hours per year stated by Brandt as the maximum number of hours worked by male adults in rural households of tropical Africa.

Finally, in this paper we have not examined buying and selling of labor, although this is clearly an important activity in both project areas. However, in the Bolilands areas the wage rate for men and women was almost identical, while in the IADP area, as in most other areas of Sierra Leone, the daily wage rate for men was about one-third higher than women.[9] This observation supports earlier findings with respect to the relatively important role of women in the Bolilands compared to the IADP area. Interestingly, there is considerable hiring of labor at harvest in both areas, although household members work less at this time than in the peak planting season. With cash in hand at harvest time and an available supply of labor, some farmers are apparently willing to hire labor and reduce their own labor inputs.

Conclusions

Examination of the impact of two technological packages representing biological-chemical technology and mechanical technology in rice production in Sierra Leone has illustrated some of the interrelationships between improved technology and labor use. In a situation of a high land-labor ratio, mechanical technology can overcome peak season labor constraints and increase the acreage cultivated. Under these conditions mechanization is not labor displacing, since the increased acreage resulting from mechanization requires added labor for planting and harvesting.

Private returns to family labor are substantially increased by mechanization, but because of a large subsidy for the use of tractors the economic returns are low. The biological-chemical technology increases returns to land, but because of a large increase in labor requirements the returns to labor are below that for traditional swamp rice cultivation. These results have significant implications for policy in Sierra Leone. Under present costs and factor endowments both technologies have low economic returns. Other technologies that have higher returns to peak season labor such as improved seed and fertilizer for upland rice should be given greater emphasis (Spencer).

Analysis of total family labor inputs in the various systems demonstrated that peak season labor demand is indeed a constraint to increased production since farm families are working at capacity during this period. Moreover, there is relatively little underutilized labor among the sample of farmers, even if 2,000 hours per year are taken as an upper

[8] We should raise a note of caution that the two areas compared here include two different ethnic groups. Work is now underway to examine the role of women in different production systems and ethnic groups in Sierra Leone.

[9] Based on 551 observations in IADP and 407 observations in the Bolilands, an analysis of variance showed significant seasonal differences in wage rates in both areas at the 1% level and significant sex differences in the IADP area only.

bound for labor use. Finally, the results suggest some important interrelationships between use of improved technology and division of labor by sex. Biological-chemical technologies increased the male labor input but did not affect female labor inputs, while mechanical technology increased female labor inputs but male labor slightly declined.

Finally, this analysis demonstrates the need for detailed information to evaluate the impact of new agricultural technologies on the demand and supply of labor. Under the conditions examined, clearly the use of labor in the peak season should be a priority consideration in the development of technological packages for small farmers.

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A View of the Plan Puebla: An Application of Hierarchical Decision Models

Christina H. Gladwin

What does a decision-making study tell project planners in developing countries about designing a rural development project for small farmers? The results, summarized here, of a study of farmers' decisions regarding the recommendations of the Plan Puebla should begin to answer this question. The Plan Puebla is an agricultural development project that was started by Centro Internacional de Majoramiento de Maiz y Trigo (CIMMYT) in 1967 and is now run by the secretariat of agriculture in Puebla, Mexico. Its aim is to increase yields of maize on rainfed farms. Initially, the project's breeding program attempted to find improved maize varieties or hybrids that performed appreciably better than the local variety (*criollo*). When the program found none, the project focused on deriving recommendations about fertilizer use and timing and plant population for the local variety (CIMMYT).

The aim of this study was to view the Plan Puebla through the eyes of the proposed adopters of the new technology—the farmers. The study focused on the decision-making processes of a small sample of farmers in one village concerning the recommendations of the plan in order to identify the factors limiting adoption of the recommendations. The recommendations for the village in 1973–74 were to get credit for fertilizer, to increase plant population, to increase the number of fertilizer applications, and to use a recommended level of fertilizer per hectare. Since farmers seemed to decide to adopt each of the first three recommendations independently of the other two, separate models of the first three adoption decisions were developed. In order to identify the factors limiting adoption of the fourth recommendation, a simulation model of the quantity of fertilizer per hectare demanded by individual farmers was developed. Since farmers first adopted fertilizer in 1962, the model focuses not on the decision to adopt fertilizer, which occurred long enough ago to cause problems in modeling and data collection, but on the decision to increase or decrease fertilizer use since then.

Before particular decision models and results are presented, a discussion of the form of the decision model used is in order. Recently, social scientists have argued that people, in choosing one alternative over other available alternatives, do not make complex calculations of the overall utility of each alternative. Rather, people tend to use procedures that simplify their decision-making calculations (Simon, Cyert and March, Tversky, Quinn). Hierarchical models or trees, with decision criteria at the nodes or branching points of the tree, can represent such procedures. The tree form of the decision model is the product of a theory of the choice process that takes into account the simplifying procedures people use in "real-life" decision making.

A Hierarchical Theory of Choice

The theory assumes, following Lancaster and Tversky, that an alternative is a set of characteristics or aspects. An aspect is a dimension or feature of an alternative. For example, the aspects of a car (in a hypothetical choice between alternative used cars to buy) could be its cost, miles per gallon, shape, and outside appearance. Furthermore, the theory assumes that all aspects are discrete. Thus, when decision makers use a continuous quantitative dimension such as cost, they either treat it as a constraint (e.g., is cost $\leq$ \$4,000?) or they categorize it such that only an ordering or a semiordering with noticeable differences of the alternatives on the aspect ($cost_{car\ 1} < cost_{car\ 2}$) will influence the choice. An algebraic representation of the choice process follows from this assumption.

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The theory tries to explain how people in everyday life make choices over a large number of objects. A car buyer, in trying to decide which used cars to look at today, might pick up a newspaper with several hundred cars listed and arrive at three used cars that interest him after fifteen minutes of scanning the page. This theory says that the person has gone through the first of two stages in the choice process. In stage I, identical to Tversky's choice process of elimination by aspects, the decision maker has eliminated rapidly and often unconsciously all cars that have some aspect that he does not want: he does not want a truck, van, convertible, or two-door sedan; he does not want a car more than four years old. He is then left with a small, manageable number of alternatives (two or three) that he can see and decide about in a more detailed way.

The latter, "hard-core" decision process occurs in stage II. People typically go through stage I quickly and think that the real decision process is stage II. In that stage, the decision maker chooses among the two or three alternatives by first listing all aspects of the alternatives and then eliminating aspects on which alternatives have equal or equivalent values. For example, if the two alternative cars in the choice both satisfy a cost constraint, i.e., they are both under $4,000, then the car buyer eliminates the aspect "is cost ≤ $4,000?" and makes no further use of it in the decision process. Then, when aspects of the two or three alternatives are themselves narrowed down to a manageable subset, the decision maker picks one of the aspects to order the alternatives on; e.g., miles per $\text{gallon}_{\text{car 1}} >$ miles per $\text{gallon}_{\text{car 2}}$. Then he formulates constraints from the remaining aspects and passes the ordered alternatives through the constraints. If the alternative ordered first on miles per gallon does not satisfy all the constraints, the alternative ordered second on miles per gallon gets a chance at them. If no alternative passes all the constraints, another strategy is employed. Therefore, the "hard-core" choice process is essentially an algebraic version of "maximization subject to constraints," a choice principle found in any microeconomics text (Henderson and Quandt). The "hard-core" choice process is algebraic, since there is an ordering of alternatives on an aspect rather than maximization of a continuous aspect. Therefore, the process may be represented by an algorithm, a decision tree, or a set of decision rules.

Methodology

Given a theory of "real-life" choice, a plan to apply the theory to a particular decision is necessary if one is interested in more than the psychological processes underlying choice. The major methodological concern is to find the specific aspects and constraints decision makers are using. One must determine what information is actually used in making decisions, as opposed to information unused in decision making that may nevertheless be given in response to interview questions.

Producing a decision-process model can be considered to have five steps.

Step 1. Observe the decisions made by a small sample of twenty to thirty decision makers. Given their decision behavior, observe and elicit the decision criteria that decision makers use in their "rules of thumb" or decision rules. Discovering decision criteria is the most difficult part of the model-building process and is described in depth elsewhere (Gladwin). Essentially, the method involves going back and forth between controlled interviewing (and acquiring information by direct observation) to produce a hypothesis about the specification of the decision criteria and testing of the hypothesized criteria against the choice behavior of the sample of decision makers.

Step 2. Using the language and categories that the decision makers themselves use, put the decision criteria into a flowchart.

Step 3. To be sure that the flowchart is descriptively adequate, test its predictions against the decisions made by the sample of decision makers used to build the flowchart.

Step 4. Model the flowchart, i.e., give an economic interpretation to the language and categories decision makers use. From the flowchart, a purely descriptive statement of the decision process, the researcher must find the underlying ordering aspect and constraints of the theory. Depending on what the flowchart says, the alternatives can be ordered on any aspect: profit, cost, risk, welfare of the group, etc.

Step 5. Test the model by using it to predict the decisions made by a new, different (if possible, random) sample of decision makers.

In the process of building the models of the decisions to adopt the recommendations of the Plan Puebla, twenty-five farmers were interviewed; in the process of testing the models, another sample of thirty-four farmers in the

same village were interviewed. In the test, each node or decision criteria in a model was a question in a questionnaire. Therefore, given a farmer's responses to the questionnaire, the model predicts what the farmer's choices will be. For example, in figure 1, the decision to increase fertilizer use, the decision maker must pass, i.e., satisfy, all the criteria on the left-hand path of the tree in order for the model to predict that he choose the outcome in the box at the end of that path, i.e., "increase q_f/ha." The six errors on that path are farmers who pass all the criteria on the path but did not try an increase in fertilizer use at that time. Since the aim of a decision model is to predict the farmer's decisions, the proper test of the model is percentage predictability, i.e., the ratio of correct predictions of farmers' choices divided by the total number of farmers who made the choice.[1] For brevity, the results of the test of each decision model will be presented along with the explanation of the model.

Decision to Increase (Decrease) Fertilizer Use

The main subroutine in the model of individual demand for fertilizer is the decision to increase (decrease) fertilizer use in figure 1. A farmer is sent to subroutine INCQF if at any time in the period after adoption of fertilizer he has a reason to change fertilizer use. A farmer may make up to four changes in fertilizer use during the period, which varies across farmers from one to eleven years. A farmer has a reason to change fertilizer use if external factors change (e.g., the bank gives him credit for more fertilizer, the available fertilizer technology changes, or the relative price of fertilizer to corn changes) or the farmer changes his production technology (e.g., he increases plant population or the number of applications of fertilizer). In subroutine INCQF, a farmer will increase the quantity of fertilizer per hectare (q_f/ha) at time t (i.e., he will go down the left-hand path to the box "increase q_f/ha") if he thinks that more fertilizer is profitable (the value of the marginal product of fertilizer

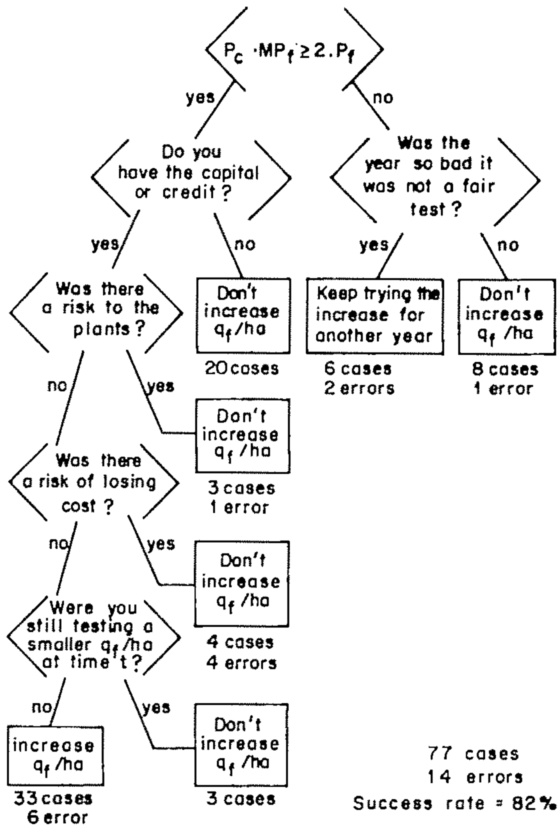

Figure 1. Subroutine INCQF

(MP_f) is at least two times its marginal cost or price ($p_c MP_f \geq 2p_f$)[2]), he can also pass a capital or credit constraint and risk of loss of plants and input costs constraints, he is not still experimenting with a smaller amount of fertilizer at that time. If the farmer fails one of any of the constraints, then the model predicts that he does not increase fertilizer use, i.e., he goes down a path leading to the outcome "Don't increase q_f/ha." The exception of this rule, on the right-hand path, occurs when the farmer finds an increase not profitable because bad weather made a fair test of more fertilizer impossible. In that case, the model says to repeat the trial for another year.

[1] The problem of the statistical significance of each path on a tree can be thought of as a quality-control problem: the farmers are passing through quality criteria designed to weed out the noninnovators. Then, on each path, one can use a t-statistic to see if the number of errors on the path is significantly different from zero. Therefore, one should interpret the t-statistic on a path in terms of the number of observations on that path. The size of the sample in this study is too small to adequately test for the significance of each path.

[2] The price of corn and fertilizer are p_c and p_f. The number 2 was chosen as a threshold value of the net return per dollar spent for fertilizer ($p_c MP_f/p_f$) because it is a number that has popped up repeatedly in the literature (Timmer, p. 200) and in interviews with farmers in the village. Its value is higher than that for the profit-maximizing farmer because the profitability question asked for a judgment given conditions of good weather and good labor (quality). The model assumes that one simplifying procedure farmers use is to look at one side of the coin, the profitability of more fertilizer under good conditions, and then at the other side of the coin, the risk of possible losses under bad conditions. Expected profit is not used as the profitability criteria because it is too complicated a calculation to be a decision criteria.

Data about seventy-seven past actual or contemplated changes in fertilizer use tested figure 1; of these forty were actual increases and two were decreases. Of the thirty-five cases in which the farmer did not try more fertilizer, twenty were cases in which the farmer did not have the necessary capital or credit. (Most of these twenty contemplated changes occurred before credit was introduced to the village in 1969–70, when the Plan Puebla started.) Hence, lack of capital or credit and not riskiness or nonprofitability was the main factor limiting fertilizer use in the past.

Figure 1 predicts 82% of the seventy-seven test cases successfully. As one can see by looking at figure 1, the main error in the model is found in the specification of the risk of losing input costs constraint. Farmers said yes, there was a danger of losing the added costs of more fertilizer, but they were willing to take the risk and increase fertilizer use anyway, whereas the risk constraint in figure 1 allows the farmer to take no perceived risks, however small. The failure of this risk constraint in all of the adoption decision models led to a reformulation of both the risk of losing plants and input costs constraints (Gladwin). The failure of this risk constraint does show, however, the advantage that a tree model has over other decision models in pinpointing exactly where the errors of the model are.

Decision to Increase Plant Population

Traditionally, farmers in Puebla plant three or four seeds per hill (*mata*) of corn with hills 70 centimeters apart. Thus, they have a seed population of 55,000 per hectare and a plant population of 36,630 plants per hectare if two-thirds of the seeds germinate. The agronomists of Plan Puebla recommend, for the village, 3,2,2 seeds per hill with hills 40 centimeters apart or 64,000 seeds per hectare or 42,624 plants per hectare if two-thirds of the seeds germinate, an increase of 6,000 plants per hectare. Most farmers in the village in 1974 knew that the plan's recommendation was to plant the hills closer (at 40 rather than at 70 centimeters), but they did not know that the recommendation called for fewer seeds per hill. They thought that the recommendation was to plant at 40 centimers with three or four seeds per hill or 96,200 seeds per hectare or 64,165 plants per hectare if two-thirds of the seeds germinate, an increase of 27,500 plants per hectare. However, the plan's agronomists say that this is too high a plant population given the soils and rainfall in the area and adopting 40 centimeters at 3,4,3,4 seeds per hill will decrease rather than increase yields. Instead, the recommendation is to distribute the plants more evenly with only 3,2,2 seeds per hill.

Therefore, the top node in the decision to increase plant population is a knowledge constraint that divides the sample of farmers into two subsets. (The flowchart is omitted for brevity.) One set of farmers decides about adopting 40 centimeters at 3,2,2 seeds per hill, the real recommendation. The other set of farmers decides about adopting "the wrong" recommendation, 40 centimeters at 3,4,3,4 seeds per hill. Both sets of farmers, in deciding between 40 and 70 centimeters, maximize gross returns (yields-cash costs) subject to the risk of losing plants and input costs constraints and a capital or credit constraint. Data from decisions made by twenty-six farmers tested the model. Lack of knowledge of the real recommendation was clearly the main factor limiting adoption of the recommendation, since fourteen out of twenty-six farmers failed the knowledge constraint. Of the remaining twelve decisions, three farmers were ready to try (or did try) the recommendation. The model successfully predicts 85% of the farmers' decisions about plant population.

Decision to Fertilize Two Times Instead of Once

Traditionally, farmers in Puebla fertilize once, at the first weeding, which occurs when the plants are 10 to 20 centimeters high, or about twenty days after planting. The Plan Puebla, however, recommends fertilizing twice, at planting and at the second weeding, which occurs when the plants are 50 centimeters high or about forty days after planting. However, no farmer in the village in 1973–74 fertilized at planting in all his fields, and few farmers fertilized at planting in one field.[3] (Most farmers in the village have one or two irrigated fields and three or four unirrigated fields.)

The decision model in figure 2 states that farmers will try to fertilize twice, at planting

[3] Although no official numerical estimates were available, unofficial estimates from extension agents were that only a small percentage of farmers in the entire region served by the Plan Puebla fertilized at planting.

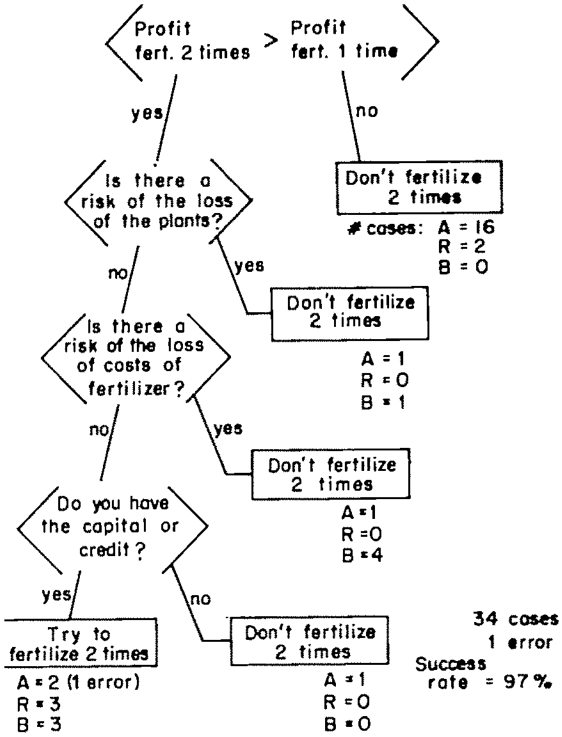

Figure 2. Decision to fertilize twice, at planting and the second weeding

and the second weeding, if they think fertilizing at planting is profitable, and they can pass the risk of loss of plants and input costs constraints and a capital or credit constraint. The model is more complicated than shown, as the profitability criteria is itself a set of criteria or logical statements of the form: If you do X in a field of type Y, then fertilizing at planting is profitable. The criteria forming a profitability judgment are different for different types of fields. In the village, there are roughly three types of fields: type R, fields with irrigation; type A, fields without irrigation but with enough moisture in the soil if plowed correctly after the preceding harvest so that the farmer can plant early in April; and type B, fields without irrigation and without moisture in April so that the farmer must wait for the first "regular" rain to plant, which may occur in April or May or as late as June. Usually there is sprinkling (*lloviznitas*) in April but no regular rain. Type A soils are called "*suelos de arena*" and contain volcanic ash; type B soils are "*suelos de barro*" or sodiclike soils (CIMMYT, pp. 2–4).

The profitability criteria for type A soils say that, if a farmer plants early in April "in dryness" (*en seco*) and does the first weeding before the first regular rain, then it is not profitable to fertilize at planting. The soil is too dry at planting to let the fertilizer dissolve, so that it just sits there on top of the ground until the first regular rain. A good farmer, i.e., one who follows the best set of observed practices to grow corn in the village, should do the first weeding (and fertilize the corn) before the first regular rain anyway.[4] There is no head start for the plants with fertilizer at planting for a good farmer with type A soils. The profitability criteria for R and B soil types say that it is profitable to fertilize at planting in fields that are moist at planting (soils wet by irrigation or by a previous regular rain) because the fertilizer will dissolve at planting and give the plants a head start. (Plants in type B soils, because of later planting, can use a fast start if they are to withstand too much water from the heavy rains (*los aguacerros*) that come in the middle to end of June.)

Data from thirty-four farmers were used to test the model. The main factor limiting adoption of the recommendation on type A soils was nonprofitability—sixteen out of twenty-one farmers with type A soils did not think it was worth the effort to fertilize at planting. On type R soils, three out of five farmers were willing to try (or did try) fertilizing twice. For five out of eight farmers with type B soils, the factor limiting adoption was risk of loss of plants or input costs. The model successfully predicts 97% of the farmers' decisions about fertilizing at planting.

Conclusion

The question initially posed about the usefulness of a decision study can now be answered. Only a study of farmers' adoption decisions can pinpoint the critical factors or intervention points in the decision process that policy makers can affect. Clearly, knowledge of the main factors limiting adoption is a necessary but not sufficient condition for speeding up the adoption process. The two aims of a decision study

[4] The best set of observed practices to grow corn in the village involves early planting in April so that the first weeding and fertilizing can be done before the first regular rain and the second weeding can be done before the first heavy rain (*aguacerro*), which is expected after 13 June. If it pours before the second weeding is done, the ground may be too muddy for the animals and plow to enter the field. Later, the plants may grow too tall for the animals to fit between the rows of corn. If the hilling-up operation in the second weeding is not done, there is more possibility of the plants' lodging later in the season in a wind.

should be to identify decision factors amenable to policy variation and to recommend changes that will speed up adoption of a project's recommendations.

This is not always an easy task, as demonstrated by the previous studies of the Plan Puebla that attempted to show that farmers' risk aversion is a factor limiting adoption. Whereas results obtained by Martín del Campo and Winkelmann do not support the argument that risk plays a prominent role in farmer decision making, results obtained by Moscardi do. However, Moscardi's results are clouded by the fact that he derives what he assumes is a risk measure, but he does not test how important risk is as a limiting factor to adoption, or if what he calls risk aversion is really nonprofitability or lack of credit or knowledge. In my judgment, one can only see how important risk is to adoption by formulating a risk constraint and including it with other factors, e.g., profit and availability of credit and inputs, in a model of an adoption decision that can be tested directly.

Because a decision model with profit, risk, capital, and knowledge as decision criteria was built for each recommendation of Plan Puebla, this study was able to pinpoint a critical node or main factor limiting adoption of each recommendation in the village. In the decision to increase fertilizer use it was lack of credit; in the decision to increase plant population, lack of knowledge of the real recommendation; and in the decision to fertilize twice, nonprofitability of the recommendation on type A soils. These results show that the critical factor or intervention point in the decision to adopt one recommendation in "the package" is not necessarily the factor limiting adoption of another recommendation. This finding differs from that of previous studies done in Puebla because those studies combined the three adoption decisions under one behavioral assumption. Thus, the methodology used precluded their finding different critical factors for different recommendations and their suggesting policy changes specific to each recommendation. The results of this study suggested the following changes in policy: increase the amount of fertilizer per hectare given to farmers on credit in the village, improve communication between extension agents and farmers in the village, especially about the topic of plant population, and drop the recommendation to fertilize at planting on type A soils. Obviously, the more practical and detailed the proposed policy changes are, the more relevance they will have for project coordinators.

The study presented here was undertaken *ex post*. Ideally, within the context of policy planning, this type of decision study should be undertaken at an earlier stage in the design of a project, e.g., after the pretest or first trial of an innovation on farmers' fields. At that stage, one can look at the decision processes of early adopters with the aim of speeding up the diffusion process. It may be possible, however, to do an *ex ante* study of farmers' choices between "the old way" and a hypothetical recommendation with the aim of eliminating "bad" recommendations. ("Bad" recommendations cause "bad" demonstrations of new techniques and much laughter among older and wiser farmers.) Another possible direction for future research lies in broadening the base of a decision study from a village to a regional level. Although the results from this study are not generalizable to the region, it should be possible to conduct a similar type of study on a regional basis.

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Impediments to Technical Progress on Small versus Large Farms

Richard Perrin and Don Winkelmann

During the past four years, Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) has been associated with a number of farm-level studies of the adoption of new wheat and maize varieties and fertilizer use. Most of these studies have now been published, and it is our purpose here to summarize some of the findings with respect to impediments to farmer adoption of new varieties.

Farm-to-farm differences in the date of adoption or the extent of adoption of new technology might be explained by a number of considerations. The studies reviewed here considered farm-to-farm differences in the cost of acquiring and processing information, differences in the physical productivity of the new technology, differences in incentives due to tenure arrangements, differences in the cost of inputs, differences in prices received for the product, differential aversion to risk among farmers, and scale effects associated with farm or enterprise size. Policies to stimulate more rapid or more extensive adoption will vary in their success depending upon which of these factors are the most important in limiting the rate and extent of adoption. Of particular relevance is the extent to which small farmers lag behind large farmers in adoption and which of the above factors might account for that lag.

The studies were directed toward factors explaining differences in adoption of new varieties and fertilizer among farmers surveyed in a number of countries in 1972 and 1973. Since seeds and fertilizer are nearly completely divisible, one might ask why farm-size effects might be expected at all. First, there are likely to be economies of size in transaction costs. It takes about the same effort for the small and large farmers to acquire and evaluate information about a new technique, to learn how to use it, and to make the purchase transaction. For an increase in net returns of $20 per hectare, the effort might be quite worthwhile for a 10-hectare farmer but not for a 1-hectare farmer. These transaction costs will fall as community experience with and information about the new technique becomes more common. Because of this, the phenomenon of economies of size in transaction costs can lead to a lag in small farmer adoption even though ultimate adoption levels may be the same as on large farms. Hence, we will more likely observe size effects during the early phases of the adoption cycle.

Furthermore, experimentation with new techniques involves the risks of the unknown, usually involving additional investment, and small farmers may be less able to undertake such risks. This risk effect can lead to lower equilibrium levels of adoption or to a lag in adoption by smaller farmers until the risks of the unknown are reduced with experience in the area. A third potential source of size effects is that smaller farmers may face higher input costs—i.e., quantity discounts might be available or government subsidies of information, credit, or inputs may favor larger farmers.

The Study Areas

CIMMYT has been associated with maize adoption studies in Kenya (Gerhart), Colombia (Colmenares), El Salvador (Cutié), and Mexico (Perrin) and with wheat adoption studies in Tunisia (Gafsi) and Turkey (Demir). In addition, Vyas undertook, at CIMMYT's request, a review of the studies of wheat adoption that had been conducted in India. While the primary focus of these studies was the adoption of improved varieties, fertilizer use was also examined to some extent in each. The percentage of surveyed farmers who had

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Views expressed in this paper are not necessarily those of Centro Internacional de Mejoramiento de Maiz y Trigo or North Carolina State University.

adopted improved varieties at the time of the studies ranged from 20% among Colombian maize growers to 67% among Kenyan maize growers (though adoption rates for subregions were as high as 100%).

The adoption trends shown in figure 1 help to provide the dynamic contexts of the adoption processes at the time the studies were conducted. Adoption of hybrid maize in western Kenya shows the most stable growth pattern, with use increasing steadily at the rate of an additional 8% of the farmers adopting each year after the hybrids were introduced in 1964. This rate slackened somewhat in the year immediately preceding the survey. Increases in the adoption of hybrid maize in El Salvador and Colombia have been both more modest and more irregular. While the earliest hybrids were introduced into El Salvador in the late 1950s, not until after the introduction of H3 and H5 (after 1966) did the increase in use of hybrids become steady. In Colombia, on the other hand, the level of hybrid use has been relatively static in the past ten years.

High-yielding varieties of wheat were first introduced commercially in India in 1966–67. There followed a rapid adoption of these varieties by about 30% of the farmers within two years. The adoption level began to rise again after 1970, as irrigation facilities were extended and improved, until nearly 60% of Indian wheat was in new varieties by 1973. The data reported by Vyas were largely gathered in 1969–71, after the initial surge of adoption had slowed. In the coastal spring wheat areas of Turkey, very rapid adoption of Mexican varieties occurred the first two years following their introduction in 1967. A second very rapid rise in the use of new varieties occurred in 1972 and 1973 after the introduction of the Russian winter variety Bezostaya into the winter wheat-producing areas of Thrace and Marmara. In Tunisia, on the other hand, adoption of the Mexican bread wheat varieties increased only slowly from their introduction in 1968 until 1970, after which adoption fell, reportedly due to problems with seed quality. The majority of new varieties adopted there

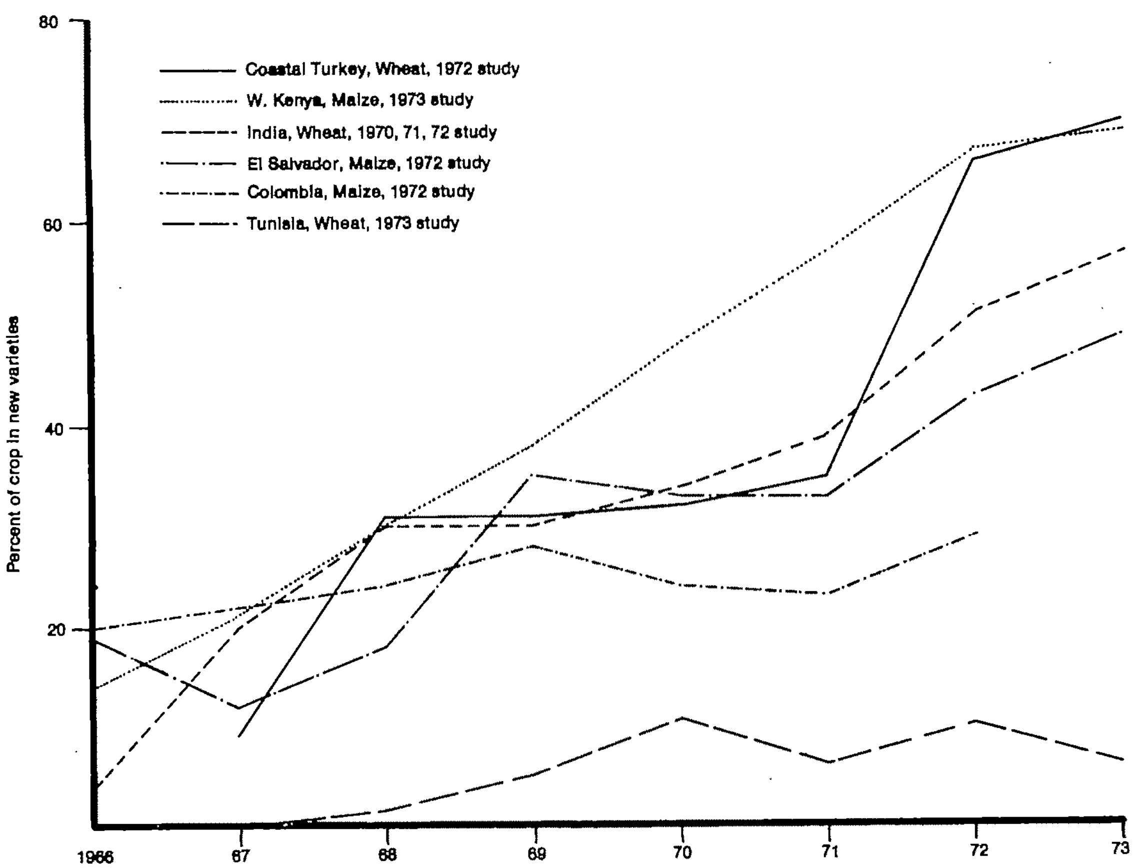

Figure 1. Trends in adoption of new varieties in the study areas

are high-yielding varieties of durum wheats (durums constitute three-fourths of the national wheat acreage).

In each of the survey studies, the population to be studied was prestratified by an agroclimatic zone as determined in collaboration with agricultural scientists. The samples were later poststratified into size groupings. Analytical procedures included both multivariate analyses and interpretation of two-way tables. This summary is restricted to a general interpretation of the results of somewhat diverse analytical approaches to a similar issue.

The Effects of Farm Size and Other Factors on Variety Adoption

In table 1 is presented the levels of adoption of new varieties by farm-size groupings within agroclimatic zones of the study areas. In about half of these situations, there appears to be little relationship between farm size and adoption, occurring in areas of Kenya, India, and Turkey, where adequate time has elapsed since introduction and nearly all farmers have adopted regardless of size, and in the medium and high valleys of Colombia, where few farmers have adopted but little additional diffusion has been taking place (figure 1). In these areas equilibrium levels of adoption appear to have been realized, and little correlation between farm size and adoption decisions is expected.

The multivariate analyses in the cited studies offer some insight into which factors are important in explaining farm-to-farm differences in adoption behavior in areas where equilibrium adoption levels have not been

Table 1. Farm Size and Percentage of Farmers Adopting New Varieties

Crop and Area	Number of Farmers	Farm Size Limits (ha.)	Percentage of Farmers Adopting by Farm Size		
			Small	Medium	Large
Kenya maize					
High, wet	96	3.2	96		96
High, dry	93	4.5	84		95
Low, dry	95	2.4	15		17
Colombia maize					
Low-valley	203		19		65
hillside	49	2.6	0		15
Medium-valley	50	2.6	19		30
hillside	170	2.1	10		15
High-valley	135	1.0	5		12
hillside	126	1.5	4		4
Salvador maize					
Valley	177	1.4, 3.5	34	46	71
Hillside	126	1.4, 3.5	28	13	36
Veracruz maize					
Valley	42	1.0, 3.5	27	37	55
Hillside	69	1.0, 3.5	18	32	36
India wheat					
Kota	100	4.5, 13.6	52	61	81
Faisabad	60	4.5, 13.6	47	100	100
Karnal	60	4.5, 13.6	100	100	100
Amritsar	100	4.5, 13.6	100	100	100
Saharanpur	60	4.5, 11.4	36	76	86
Ferozepur		4.0, 11.0	93	96	100
Muzaffarnagar		4.7, 10.7	37	55	57
Turkey wheat					
Mediterranean valley		6.0	95	66	97
hillside		8.0	92	134	90
Aegean valley		3.9	60	39	77
hillside		4.6	4	115	23
S. Marmara valley		4.4	70	41	43
hillside		3.4	13	136	32
Thrace hillside		8.0	62	171	85
Tunisia wheat					
Low rainfall	175	15.0, 40.0	15	43	57
High rainfall	200	15.0, 40.0	13	34	66

Sources: Gerhart, Colmenares, Cutié, Perrin, Vyas, Demir, and Gafsi.

realized. The factors considered varied from study to study but included zone and topographic variables to capture differences from farm to farm in yield superiority of the new varieties, plus variables representing differences in farmer incentives arising from input and product prices, differences in farmer perceptions of or reactions to risk, and farm-size effects. Due to the differences from study to study in variables used and analytical techniques, only a brief summary (table 2) of the results of these multivariate analyses is presented. For each factor included in the analysis, either a yes or a no is entered in table 2, yes if the factor was significant statistically (t-ratios of 1.5 or more) with a coefficient sufficiently large to be of practical significance, and no otherwise.

A cursory glance at table 2 shows that productivity factors—agroclimatic zone and topography—are the most consistent in explaining why some farmers adopt new varieties and others do not. While these factors were generally far more important in explaining behavior than any others, we are convinced that much more of farmers' adoption behavior could have been explained by productivity considerations had more accurate measurement of agroclimatic factors as related to productivity been possible. This became clear in retrospect, for example, as some villages within a few miles of one another in the Aegean area of Turkey where farmer adoption patterns seemed to make little sense were reexamined. The elevation of one valley village was just enough higher than the others that frost problems precluded the use of new varieties, and no farmers were using them, though some had tried. Within a lower valley village, the land parcels were divided between two types of valley land—a lower alluvial terrace and an upper alluvial terrace. The upper terrace soils were shallower and lighter than those of the lower terrace, and soil water capacity was so low that farmers preferred the local varieties, which yield as well as the new varieties under limited rainfall conditions where little fertilizer is used.

Thus, within a small geographic area, we had observed three villages, ostensibly similar, with markedly different patterns of adoption: no adopters in one village, nearly all adopters in a second, and a mixed pattern of adoption in a third. Yet with a better insight into agroclimatic factors affecting the productivity of new varieties versus the old, this pattern of behavior was understandable apart from considerations of information, prices,

Table 2. Factors Explaining Within-Region Variability in Farmer Decisions to Adopt Improved Varieties

	Maize				Wheat	
	Kenya	Colombia	El Salvador	Veracruz	Tunisia	Turkey
Percentage of adopters (%)	67	20	36	34	31	64
Productivity						
Agroclimatic zone	yes	yes			no	yes
Topography		yes	yes	yes	yes	yes
Information						
Schooling	yes	yes	yes		no	no
Extension visits	no	yes				
Demonstrations	yes			yes		no
Age	no					no
Tenure		no			no	no
Inputs						
Credit-use		yes	no	no	yes	
Credit-availability	yes				no	
Co-op membership						yes
Product market						
Variety discounts					yes	no
Market sales of crop				no		no[a]
Risk						
Perceived yield risk			no	no		yes
Use of drought crops	yes					
Off-farm income	no			no	no	no
Farm size[b]	no	yes	no	yes	no	yes

Sources: Gerhart, Colmenares, Cutié, Perrin, Gafsi, and Demir.
[a] Market participation was important in one of four Turkish regions.
[b] Farm size was important in one of three Colombian and in two of four Turkish regions.

and risks. It was not that agroclimatic factors were not considered prior to the study but rather that relatively subtle agroclimatic gradients can lead to dramatic changes in farmer behavior. Gerhart's Kenya study and an as yet unfinished maize study in Pakistan reinforce this observation, as do studies with rice (Barker). It is also stressed by Evenson (p. 201) and his coworkers. Gerhart concluded that "if anything, this study shows how very site-specific agricultural technology is, even within one region of one (admittedly very diverse) country" (p. 26).

These experiences force the recognition that, within any farming area, there exists a wide range of expected yield increments from a given new variety or new technology. The differences can be the result of gradients in soil depth, texture, or other characteristics, differences in quantity of rainfall or irrigation water, differences in nighttime low or daytime high temperatures in certain seasons, differences in disease incidence related to these factors, and so on. In a truly homogeneous agroclimatic zone, the frequency distribution of expected yield increments across farmers' fields would be bunched rather tightly about the mean. For practical purposes, however, either for developing and recommending new technologies or for analyzing farmer behavior, we must deal with groups of farmers for whom the frequency distribution of expected yield increments will not be very compact due to agroclimatic variability. Because of this, identification of the extent to which productivity factors are affecting farmers' decisions versus differences in economic factors, such as information, tenure, input and product markets, scale economies, etc., will be difficult.

Turning now to the effect of these economic factors in the six studies, with some exceptions farmer behavior was not found to be significantly or consistently related to them. One exception was the availability or use of credit. In four of the six studies in which it was considered, this variable was significantly related to the adoption of high-yielding varieties. However, even though farmers using credit were more likely to be using new varieties (44% more likely in Columbia for example), this does not necessarily imply that the existence of credit programs is critical to farmer adoption decisions. Where a new variety or new technology is marginally profitable, the subsidies implied by government credit programs could be expected to affect many farmers' decisions. But if the new technology is profitable even at unsubsidized capital and input prices, farmers could be expected to adopt the technology and to purchase the inputs through the credit program if it in fact provided capital and inputs at subsidized prices. In the latter case, we would see a high correlation between the use of credit and adoption, even though the credit program itself had little effect on the adoption decision.

Market conditions accounted for very little of observed adoption behavior. Differences in price discounts for new wheat varieties from village to village in Tunisia were significant in explaining farmer adoption decisions, but this was the only case in which product market circumstances or market participation were related significantly to new variety adoption. The availability of seed appeared to be a limiting factor in adoption of winter wheats in Turkey and durum wheats in Tunisia, where the introduction of new varieties was fairly recent and seed multiplication had not kept pace with farmer demand.

Differences in the cost of acquiring and processing information as measured by extension activity and schooling had only a slight relationship to adoption. Extension visits or demonstration attendance appeared to increase the probability of adoption by 10% to 15% in certain subregions of Colombia and Turkey, less or none in other areas. Each additional year of schooling increased the probability of adoption by an estimated 8% in Colombia, less in other areas.

The question of whether risk aversion is affecting adoption decisions was not really very satisfactorily addressed in these studies, and it is difficult to imagine how one can do so. In three studies, farmer perception of the risk of low crop yields was used as an index of farmers' risk aversion, while in Kenya the existence of drought resistant "famine" crops was used. While these indexes were in general correlated with adoption, the interpretation of this result is not straightforward. It is true that where crop failures are more common, risks are greater. But it is also true that where crop failures are more common, average yields will be lower. Where farmers perceive high risks of crop failure, reluctance to adopt could be evidence of risk aversion or simply evidence that the average returns to adoption are too low. To determine which of these factors are contributing to the observed correlation, more specific information is needed than was avail-

able about farmer perceptions of expected yields versus yield risks for both new and old varieties.

This brings us again to the question of the relationship between farm size and adoption decisions. In about half of the agroclimatic situations of table 1, farm size appeared to have an important effect on adoption. Yet in the multivariate analyses, farm size was not correlated with adoption decisions in some of these areas. In the low elevation areas of Colombia, where table 1 indicates an important size effect, the multivariate analysis showed that once credit and extension contacts are considered the residual effect of size was minor, with each hectare increase in size being associated with only 0.1% increase in the probability of adoption. After a careful consideration of extension and credit activities, Colmenares concluded that the orientation of these programs toward larger farmers contributed substantially to the greater adoption rate among larger farmers. In Tunisia, it appears that smaller farms' lower adoption rates are due to differences in topography, credit use, and local price discounts rather than to factors related to farm size per se. The multivariate analyses of hybrid maize adoption in El Salvador likewise fail to show any effect of farm size per se, though it is not clear yet what factors may be contributing to the apparent size effect revealed in table 1. In India, Vyas reported that most of the observed differences in variety adoption by farm size were due to differences in the availability of irrigation water and to a seed distribution policy that initially favored larger farmers.

In the remaining areas in which size effects are notable in table 1, variety introductions were quite recent in Veracruz and Mexico (maize) and in the South Marmara and Thrace areas of Turkey, and the multivariate analyses indicated definite size effects associated with adoption even when other factors were considered. Thus, of all the areas considered, only in the Aegean area of Turkey did there appear to be significant size effects in adoption that were not plausibly explained by differences in productivity, differences in effective market prices for inputs or products, or by the early stage of adoption in which small farms can be expected to lag behind larger farmers because of economies of size in transaction costs in evaluating and acquiring the new varieties.

By contrast, the scale effect in fertilizer adoption in these studies was more pronounced. Space precludes a summary of the analyses of fertilizer adoption decisions, but there were significant size effects in fertilizer adoption in nearly half of the agroclimatic situations considered. Apparently, fertilizer use is more heavily influenced by farm size than is variety use, as might be expected due to the greater investment at risk with fertilizer.

Conclusions

The adoption studies with which CIMMYT has been associated have shown that to a limited extent differences in farmer adoption behavior can be explained by differences in information, in the availability of inputs, in market opportunities for the crop, and differences in farm size and farmer risk aversion or risk perception. The pattern of adoption among large and small farms is generally consistent with the proposition that small farms may lag behind larger farms in the early stages of adoption but soon catch up. The impression from these studies is that the most pervasive explanation of why some farmers do not adopt new varieties and fertilizer while others do is that the expected increase in yield for some farmers is small or nil, while for others it is significant, due to differences (sometimes subtle) in soils, climate, water availability, or other biological factors.

Agricultural technology is more site-specific than we were led to believe by some of the early successes with wheat and rice varieties. The early high-yielding wheat varieties were adapted to extensive production areas and were widely adopted. It seems that these early successes will not be easily duplicated on such a scale. In the areas not already dominated by new varieties, the factors limiting yields are so disparate and complex as to make it unlikely that any single new variety can repeat the success of the early releases from international breeding programs.

Government policies to reduce the cost of information, the cost of inputs, or the impact of risk could be expected to influence the decisions of those farmers whose expected yield increases are now marginal. But the experience in the areas of these studies suggests that these policies are not likely to have a large impact in increasing the number of farmers who adopt new technologies. Significant advances in adoption will not occur until signifi-

cant advances are made in technologies that will increase yields in the agroclimatic environment of those farmers not presently adopting. This will require greater attention to the environment for which technologies are being developed than was necessary for the early successes in cereal breeding.

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Land Use Planning: An Institutional Overview

Raymond J. Supalla

The environmental concerns of the 1970s have spawned an extensive institutional maze designed to achieve a multiplicity of environmental goals. Land use planning occupies an important but ill-defined role within this configuration of institutions, that is, ill-defined with reference to both what land use planning is and what it can accomplish. The result is a confusion, a misallocation of research resources and planning impotence.

Land use planning is ill-defined primarily because the relationships, powers, and responsibilities of the many people involved in planning are changing rapidly (institutional change) and because there exists no theory of planning that adequately integrates the market and political aspects of land use decision making. Rapid institutional change makes it extremely difficult for analysts to maintain realistic and relevant perspectives. Similarly, the absence of a comprehensive theory of planning leaves analysts without an adequate basis for conceptualizing problems and selecting appropriate analytical concepts. This paper constitutes an attempt to improve understanding of what land use planning is and what it can accomplish by examining conceptual issues and reviewing current institutional trends. Attention is also given to assessing the reasons for institutional change and the significance of recent trends with reference to social welfare and research needs.

Discussants for this session were Orville E. Krause of the Economic Research Service, U.S. Department of Agriculture, and Daniel W. Bromley of the University of Wisconsin.

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Conceptual View of Planning

According to the conventional definition, planning is a public decision-making process involving the evaluation of land use alternatives and the implementation of direct or indirect land use control programs. This broad definition is widely accepted, but attempts to specify the planning process in greater detail reveal vastly different perspectives and are fraught with conceptual problems. Thus, it is necessary to examine some of the major conceptual problems before presenting a more detailed conceptual framework that can serve as a basis for discussing planning institutions.

Perhaps the most significant problem is the persistent belief that land use planning can be and ought to be comprehensive. Comprehensiveness calls for determining the land use pattern that maximizes social welfare. Defined in this manner, comprehensive planning can be achieved only if two conditions are met: decision makers thoroughly understand the welfare implications of all land use outputs for all the people involved and analysts are able to clearly specify the production relationships between land and social outputs, such as clean air, clean water, efficient public utility systems, aesthetic enhancement, etc. Neither of these conditions can be met at the present time, and, thus, comprehensiveness is and will probably remain an elusive and impossible goal. (For a more complete treatment of why comprehensive land use planning is an impossibility, with emphasis on the difficulties inherent in the political process, see Libby, pp. 106–8.) The major consequence of attempting comprehensiveness is production of a document that achieves nothing. Planners who attempt to do all things find themselves without

the resources to sell the public on any one of them, even though they may have acquired the data to convince themselves.

Another conceptual problem is the tendency to view land use patterns as an output or end in itself instead of an input or method of achieving desired social goals. When a given change in land use patterns is viewed as the desired objective instead of in terms of the difference made to society if the land is used differently, attention is diverted from the real purpose of planning, leading to the ignorance of methods other than land use planning as the means for achieving desired ends. For example, property damages due to flooding can be reduced by land use planning actions that discourage development of flood plains, but perhaps retention dams could achieve the same end with a more desirable cost-benefit distribution.

A third conceptual problem results from failure to understand the meaning and/or importance of analytical institutional economics. A recent article by Seagraves illustrates both the confusion surrounding the analysis of environmental institutions and the persistent tendency of many economists to succumb to the conservative bias that requires a positivistic approach and deemphasis of distributional issues. The appraisal of environmental institutions, of which land use planning institutions are a subset, demands an assessment of what difference will be made if the rules are changed and who will be affected by the impacts (Schmid, Bromley, Randall). The focus on efficiency questions, strongly advocated by economists with a conservative bias, ignores the question of whose efficiency. The ideal land use pattern (highest value output per unit of input) may be quite different for poor inner city residents than for rich suburban dwellers. Perhaps many land use plans continue to gather dust because they are designed by and for one group, planners and community activists, but must be sold to the public at large.

The foregoing discussion only touches on the myriad of conceptual problems associated with the land use planning process, but it does provide a starting point for presenting a relatively detailed conceptual perspective that is consistent with institutional reality.

Land use planning can be viewed as a process of establishing and operating public institutions that modify the market allocation of land consistent with the wishes of the people involved.[1] The process begins when groups of individuals become dissatisfied with the existing or projected market allocation of land resources and set out to change the rules (establish planning institutions) in order to allocate land resources in a manner more consistent with their wishes. The objective is not to optimize the use of land (comprehensive planning) but to use land use modifications as a means of achieving a narrow subset of social goals. Once the rules have been established, including the choice of the decision maker, the distribution of power over land use, provisions for citizen recourse, and provisions for financing planning efforts, the operational phase of planning begins. This phase consists of analysis of the difference made if land is used in different ways, selection of desired land uses, analysis of how land use patterns change with the implementation of control alternatives, and actual implementation of control programs. More precisely, land use planning can be thought of as a process of determining property right distributions at two levels. First, the rules establish whose preferences count. Second, property rights are changed to encourage land use patterns more consistent with the wishes of those whose preferences matter.

When land use planning is viewed in the above manner, it permits perception of the process as but one means of achieving desired goals. It also facilitates recognition that the outcome of land use planning depends on the distribution of rights or liability rules, contrary to those who believe that optimum land use patterns could be determined if only enough data was available. The importance of property rights means that any evaluation of planning performance must focus on how decisions vary with differences in institutional arrangements and how successful a given institution is in achieving the objectives of the people whose preferences matter. Planning performance can be evaluated with reference to the perspective of given publics, but the normative aspect of property rights makes it impossible to evaluate with reference to the total public interest.

[1] It is helpful to distinguish between land use planning and public land management, where land use planning involves public controls over private lands and public land management involves public decisions regarding public lands. Public land management is essentially a subset of land use planning where the market is rejected in favor of public ownership as a means of land use control.

Current Institutional Trends

The current state of land use planning activity can usefully be divided into two components, input-oriented and output-oriented. Input-oriented efforts include all planning institutions established for the express purpose of modifying land use patterns. Output-oriented efforts include those institutions established to pursue an express purpose other than land use planning but that employ land use planning as one of several means for achieving their goals (e.g., the Environmental Protection Agency).[2]

Since federal land use legislation succumbed to impeachment politics and the fears of the agricultural sector in 1974, the push to establish input-oriented planning institutions at a state level has abated considerably. A review of *Land Use Planning Reports* reveals that only one state, Wyoming, passed broad based input-oriented land use planning legislation during the past eighteen months and that it is being seriously considered in only one other state, Michigan. County and municipal programs are still being established, but such programs continue to be almost exclusively dependent on zoning, a control technique that is only marginally effective (Babcock, p. 123).

The real action in the land use planning arena appears increasingly to involve output-oriented efforts. Some of the more significant land planning institutions include highway departments, fish and wildlife bureaus, parks and recreation agencies, housing agencies, and, last but not least, the Environmental Protection Agency. All of these institutions engage in land use planning as one means of achieving their objectives.

Highway departments engage directly in land use planning when they set out to determine highway routes and designate arterials. This process involves analyzing the impact of highways on land use patterns. Fish and wildlife, parks and recreation, and housing agencies are involved in the management of agency-owned lands and in the control of lands owned by others as a means of insuring the availability of wildlife habitat, recreation facilities, and aesthetically pleasing housing, respectively. The Environmental Protection Agency (EPA) is involved in land use planning in many ways and is emerging as the most important of all output-oriented land planning institutions. The activities associated with implementation of the Federal Air Quality Act (PL 91-604) and Water Quality Act (PL 92-500) are perhaps the most important land related EPA programs. Implementation of the Federal Air Quality Act involves determination of where industrial and public facilities can be located, which constitutes land use planning in its purest form.

The most significant water quality program, in terms of land use, is section 208 of Public Law 92-500. Section 208, as recently interpreted by a U.S. District Court for the District of Columbia, requires a statewide program, including rural as well as urban areas. Under draft guidelines issued by the EPA, section 208 programs must, among other things, have accurate land use growth projections in order to plan for adequate waste-water management facilities and anticipated nonpoint source runoff (U.S. Environmental Protection Agency). The guidelines essentially say that section 208 planning must examine, evaluate, and make recommendations on the existing land use regulatory system and land management practices, particularly as they relate to nonpoint source control (Nebraska Natural Resources Commission, p. 3).

This brief summary of what is currently transpiring in the land use planning arena indicates that land use planning is occurring at an increasingly intensive pace in rural as well as urban America. But, the major programs are not the traditional land input-oriented programs with the multiple objectives and political decision making that is usually envisioned in state or federal land use bills. Instead, land use planning is being done by output-oriented institutions where land use decisions are made by bureaucrats and viewed as a means of achieving a single objective. Some of the reasons for this phenomenon are perhaps obvious, but it might be useful to explore them before examining the policy and research implications of this changing institutional scene.

Factors Affecting the Development of Land Use Institutions

Factors affecting the development of land use planning institutions fall into two categories:

[2] It is important to carefully distinguish between institutions that engage in making decisions about land uses for the purpose of achieving particular goals or outputs (output-oriented planning) and those who merely establish rules that incidentally influence land use. For example, tax rules influence land use, but the Internal Revenue Service does not engage in land use deliberations. The Environmental Protection Agency, in contrast, engages in both rule making and in deliberations regarding desired land use patterns.

those that create a demand for outputs affected by land use patterns and those that influence the type of institutions that emerge for the purpose of providing the outputs demanded. Each category is discussed in turn below.

The land use planning outputs that have enjoyed the greatest increase in demand are primarily environmental in character, e.g., preservation of open space, improved air and water quality, protection of wildlife habitat, and preservation of wilderness areas. The demand for these environmental products has apparently increased due to greater affluence, population pressures, improved knowledge regarding the ecological implications of man's activities, and changing life styles. There is probably no question about the general validity of these forces, but what is not well understood is the extent to which such forces vary by geographical and social dimensions. To what extent and for what reasons, for example, is the demand for environmental products different in urban versus rural communities? Casual observation indicates that the political pressures for environmental products are greatest in the more affluent urbanized regions, but little is known about why such differences exist. Are they due to different preferences (values) or to different levels of knowledge regarding ecological factors?

Analyses of public attitudes indicate that preferences or value differences explain more of the variance in demand than differences in knowledge (Comer, p. 40). If these preliminary results prove to be valid, a number of land use and other environmental programs are doomed to fail. Most notedly, land use education efforts directed at making planning in rural areas politically acceptable are not likely to succeed if the public does not want what land use planning will provide, as opposed to not understanding what the outcomes will be.

The factors influencing the type of institutions being established to provide environmental outputs are more difficult to discern, but at least three plausible forces come to mind: the relative ability of the public to identify with broad goals as opposed to techniques for achieving goals, the fact that oblique changes in property rights are more politically acceptable than direct and obvious changes, and the difficulty that politicians find both conceptually and politically in providing specific policy directions.

In this election year it appears to be particularly evident that the public identifies much more readily with goals than with techniques for achieving them. Much as Governor Carter finds it more persuasive to speak of goals rather than of programs to achieve goals, the general public is more apt to support pristine water quality than they are to support land use planning, which is usually equated with zoning. If this phenomenon is as pervasive as it appears, it would come as no surprise when Congress adopts environmental goals that require land use planning to achieve them but turns down land use planning bills.

Much of the resistance to input-oriented land use planning can be attributed to the obvious changes in property rights that occur when plans are implemented. Property rights are viewed by many lay people as being absolute and inviolate such that any change threatens the very foundations of the social structure. However, opposition to changing property rights is intense only when changes are direct and obvious. Perhaps this is due to the fact that one cannot oppose something unless one recognizes that it is occurring, or perhaps it is due to the implicit acceptance of property right changes when the resulting outcomes clearly warrant it. In either case, it is clear that oblique property rights changes, such as giving a farmer's neighbor the right to be free of the dust associated with grain storage via an Air Quality Act, are much more acceptable than a direct change such as zoning cropland agricultural.

A third important factor contributing to development of output-oriented land use planning institutions is the difficulty of making specific political decisions when the issues involved are extremely complex and controversial. Politicians at all levels of government cope with complexity by making broad policy decisions and assigning to bureaucrats and to the courts the task of working out the details and the conflicts. This phenomenon is evidenced quite clearly in the evolution of environmental law. The National Environmental Policy Act, the Water Quality Act, and the Air Quality Act were all so broad that no one knew what they meant until bureaucrats drafted guidelines (administrative law) and the courts approved or disapproved such guidelines, given their view of congressional intent. If this approach continues, and there does not appear to be a viable alternative, input-oriented land use planning efforts that

call for detailed political decision making are likely to remain insignificant.

The output-oriented land use planning institutions that emerged in recent years appear destined to continue their domination of the land use planning arena, given the nature of the forces underlying such developments. Assuming this view is correct, several critical social welfare and research issues merit attention.

Social Welfare Effects

What appears to be quite clear from the emerging pattern of land use planning institutions is that market-directed land use patterns are being drastically modified but not in the manner envisioned by many advocates of land use planning. Instead of planning efforts that seek to balance multiple objectives, the scene is being increasingly dominated by single-objective programs, e.g., water quality. Land use decisions are being made by bureaucrats and the courts instead of by the elected representatives of the people. Similarly, the emergence of strong output-oriented programs has successfully removed most of the important decisions from the local control so strongly advocated by many input-oriented planners.

The principal welfare consequence of these developments appears to be the danger that particular objectives will dominate to the exclusion of others or, more broadly, the danger that many publics will not be adequately represented as land use decisions are made. At the present time, for example, people concerned about air quality, water quality, automobile transportation systems, and the preservation of historical sites, wilderness areas, and wildlife are quite well represented, as contrasted to those publics who are interested in preservation of agricultural land, quality mass transit systems, lower-cost housing, and efficient public utility systems. Perhaps what is needed is an Agricultural Land Act, a Mass Transit Act, a Private Housing Act, and a Public Utilities Act comparable in impact to the Wilderness Act, the Air Quality Act, and the Federal Highway Act. One could then permit the courts to adjudicate the increased conflicts that result or to establish additional adjudicating bodies called something other than land use planning boards.

In considering the social welfare effects of the evolving pattern of land use planning institutions, it soon becomes clear that what has been, is being, or could be produced by alternative institutional arrangements remains largely unknown. There exists little empirical evidence to either refute or support deductive conclusions.

Research Needs

The increased emphasis on output-oriented planning efforts calls for quite different research programs than those currently being emphasized by land use planning economists. Current research programs, to the best of my knowledge, focus on property value effects of public land use decisions; the impact of incentive-based policies on land use patterns; measurement of public land use preferences; development of land use data systems; explanations for the spatial distribution of economic activity; and identification of prime agricultural lands. (This summary of current research emphasis is based on published output and inferences that can be drawn from the work of the National Task Force on Research Related to Land Use Planning and Policy.) Suggested changes in research priorities are discussed below with reference to three major recommendations.

(*a*) Additional research is needed on the outcomes associated with different institutional arrangements. With land use planning institutions in a rapid state of evolution, it is imperative for society to closely examine what differences result from alternative institutional arrangements. For example, what differences are likely to result from decisions made by elected officials, bureaucrats, and judges? To what extent do land use decisions resulting from output-oriented institutions differ from input-oriented pursuits? Does citizen participation in planning change decisions or does it simply legitimize what would have been done anyway? Answers to these and numerous related questions are essential if there is to be any hope of anything more than random achievement of land use goals.

(*b*) Additional research is needed on the relationships between land use and quality of life variables. At the present time little is known about the all important relationships between land use and quality of life variables. Specific examples that merit attention include the relationship between a sprawled urban land use

pattern and air quality; the effect of prohibiting urban development of agricultural land on the quantity, quality, and cost of available housing; and the relationship between use of inorganic compounds on cropland and the impact on potable water supplies and water-based recreation. Input-oriented planning efforts have often failed because they did not consider relevant outputs, and output-oriented efforts can succeed only if asking output-oriented questions results in credible answers.

(*c*) Increased emphasis should be placed on the efficient collection of the types of data that influence land use decisions. Perhaps the most serious malallocation of research resources occurs with reference to the collection and analysis of data for all lands, when it is relevant to decisions on only a small part of the total acreage. For example, detailed data on the physical suitability of soils for urban use are needed for areas where urban development is likely but are a waste of effort for areas where it is clear that urban development will not occur. A better more general illustration might be land resource inventories. Most land resource inventory systems call for collection of the same data for all lands within a jurisdiction, despite the fact that land use changes occur only on a small and predictable portion of the total land base.

Another malallocation occurs when researchers collect data and analyze issues that they believe important but that decision makers choose to ignore. This factor is becoming increasingly important as narrowly focused output-oriented planning institutions increase in prominence.

Summary

This institutional overview reveals that land use planning must be conceived of as a subcomprehensive public decision-making process that focuses on modifying land use patterns to produce desired outputs, with decisions made on the basis of distributional impacts, not economic efficiency. When land use planning is conceived of in this broad context, it becomes clear that the public decisions regarding land use are increasingly being made by output-oriented planning institutions such as EPA and not by conventional planning commissions. Output-oriented planning institutions can be expected to continue their rapid growth, due to the relative ability of the public to identify with specific instead of general goals, the higher acceptability of oblique changes in property rights than direct and obvious changes, and the increasing difficulty that politicians find in making detailed resources use decisions, such as those required with input-oriented planning.

Current trends in the evolution of land use planning institutions mean that increasingly it is the bureaucrats and the courts instead of politicians who are making land use decisions and that the distribution of power over land use is shifting from the local to state and federal governments. These developments pose an increased danger that particular planning objectives will dominate to the exclusion of others and that the divergent interests of different localities will not be adequately represented.

The high priority research needs associated with the changing institutional scene include evaluation of the outcomes associated with different institutional arrangements and estimates of the relationships between land use and quality of life variables. In addition, research planning needs to involve a greater emphasis on determining the data and research results most relevant to the decision-making process.

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Information Needs and Models for Land Use Planning

James A. Gibson and John F. Timmons

Public concern about the use of land resources has increased in recent years. One explanation stems from accelerating changes occurring in population patterns and life styles.[1] Simultaneously, tight world food supplies combined with environmental pressures[2] and possible changes in future technological progress[3] have led to an increased realization that land resources are relatively scarce and require improved management. Land use is closely linked to such important issues as food supply, energy resources, environmental quality, and rural and urban development.

This paper presents information needs and models for U.S. land use planning. The following steps are followed. First, U.S. land use planning is briefly reviewed in retrospect. Second, present land use information needs are discussed. Third, the concept of land use viewed as a process is introduced. Fourth, models for land use planning, based on methodologies utilized in recent land use research undertaken in Iowa and which seem to have applications in other states, are presented. Selected research findings obtained from application of these models are presented. Finally, utilization of land use information and further land use research needs are discussed.

Land Use Planning in Retrospect

During the depression years in the early 1930s, land use research and planning became evident by the establishment of the National Planning Board in 1934 and the subsequent establishment of state planning boards in most states and of county land use planning in most counties. Land use research during the first part of the 1940s was directed toward increasing agricultural production. In the postwar part of the decade, effort was directed toward land use adjustments necessitated by declining demand for agricultural products and by urban growth. During the 1950s land use research efforts extended to problems of irrigation and water rights as water use became more competitive among the major uses within the more humid areas. World land problems, aggravated by increasing world population pressures, became major concerns of land use research during the 1960s. During the late 1960s and the 1970s land use efforts were extended to environmental problems associated with soils, water, air, congestion, technology, and land resource use conflicts.

Many weaknesses experienced in land use research and planning efforts of earlier decades could now be avoided. A popular area of earlier land use research encompassed development and application of land classification techniques. As stated by Kelso, "The intent was to map geographically the patterns of physical and biological characteristics of the environment. Often the problem-solving relevance of these classifications was vague, and in most cases their economic interpretation was more vague" (p. 3). Land use research lacked defined goals and defined data needs consistent with state and national goals. There was an absence of rigorous analyses and quantitative modeling. Today, there still exists an absence of clearly defined land use goals, land use information (needed for an informed and participating citizenry), and policy tools adequate and acceptable to implement land use programs.[4]

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[1] Beale has found a nationwide shift from city to suburban and open country living near metropolitan areas.

[2] A resolution proposed by the 1975 Midwest Governors Conference includes the concern that environmental constraints and regulations established in the interest of long-term productivity may be expected to set limits on some types of short-term agricultural productivity (Midwest Governors' Agriculture Land Use Task Force).

[3] A recent study by the National Academy of Sciences finds that increases in U.S. farm efficiency (output per unit of land) may be tapering off.

[4] Infanger and Bordeaux's recent assessment of extension land use educational publications found a paucity of information trac-

Information Needs for Land Use Planning

Currently, governmental entities, recognizing the need for land use planning, are enacting land use legislation at both state and national levels. But current land use planning efforts are being thwarted and confused by vague and conflicting goals. Among such goals are orderly development of land uses, preservation of prime agricultural land, and protection of property rights.

Any land use planning system requires an information support system. Land use legislation pending at the state and national levels is likely to demand new levels of capability within the technical area of economic analysis, particularly in regard to systematic analysis of land use data. Proposed federal legislation explicitly requires states to forecast their land use requirements.[5] Both state and federally proposed legislation provide significant incentives for developing quantitative land use analysis models.

Information systems serving land resource programs have direct bearing upon the effectiveness of identifying and satisfying land use policy, planning, and program objectives. A reduction of uncertainty through land use information and projection can improve the social allocative efficiency of the land market and can improve public land use decisions with respect to land resource allocation over time.

Applied research is a necessary basis for planning future uses of land. Land use research needed in the United States includes articulation and analysis of public land use goals, inventory of present land uses and projections of future land uses, and identification and development of alternative means for achieving articulated land use goals.

No land use program can be made effective without appropriate implementation. Policy tools designed to meet the needs of an earlier era are still relied on today. Current zoning ordinances, for example, are based on a model enabling law proposed in 1922 by a U.S. Commerce Commission Advisory Committee on Zoning (Berger). Research is needed to analyze and design appropriate policy tools to guide land uses toward current goals.

Land Use Viewed as a Process

Significant progress cannot be made in land use planning until the land use process is better understood. The land use process concept views land use not as a random process but subject to causal factors that are dynamic, predictive, and normative in nature. This concept implies change in land uses over time. Each land use has an immediate impact on the adjacent land uses and also has impacts on succeeding land uses over time. Effective public land use programs require accurate understanding of past and present land uses and their interrelationships.

The predictive element of the land use process implicitly hypothesizes the existence of identifiable causal factors affecting the use of land. Current land uses have evolved through processes involving decisions and actions in both the market place and the political arena. Land use does not just happen; rather, there is a rationale for present uses of land that requires understanding and analysis. Finally, normative elements of the land use process assume that land use goals can be articulated by society and implemented by institutions, taking into account identified causal factors.

Recent Iowa land use research, divided into three highly interrelated segments, has begun to apply the land use process concept. The first segment focuses on identifying land use planning goals of residents within a multicounty planning area. The second focuses on inventorying present land uses and projecting future land uses, while the third analyzes policy tools available to guide land uses toward identified goals. A comparison of results from the first segment with the second forms the basis for detecting potential land use problematic situations. Through this approach, the need for institutions to resolve the problematic gap becomes obvious and is treated within the third segment.

Multigoal Land Use Model

Recent land use research in Iowa develops and applies methodology in the identification

ing the development of present state land use patterns. They also found that, while publications related to present control techniques (mostly zoning) are plentiful, available material on proposed new land use controls is sparse.

[5] Both S.632 and S.3175 included provisions for states to qualify for federal land use planning assistance (U.S. Congress, Senate 1971, 1972). Subsequent bills introduced in Congress—S.268, H.R.10294, and S.984—contained smaller provisions (U.S. Congress, Senate 1973, 1975; House 1974). Under Section 701 of the Federal Housing and Community Development Act of 1974, HUD 701 grants for comprehensive planning will not be approved after August 1977 unless the comprehensive plan contains a land use component (U.S. Congress).

and formulation of goals for land use planning preferred by citizens within a multicounty region (Lundeen). A model was developed that uses U.S. Water Resources Council goals for land use planning.[6] Agricultural, industrial, residential, recreation, mining, and transportation land uses are involved in achievement of these goals.

Through interviews with a modified random sample of respondents designed to reflect their age, sex, education, and occupation, in-depth interrogation of respondents revealed the identification and ordering of the following land use goals: increased environmental quality and conservation of resources, increased economic development of the region, and improved social well-being in terms of income distribution and levels of living. A paired-comparison model was used to provide an estimate of each goal's numerical position on a scale in addition to an ordinal ranking of the goals (Edwards).

Land Use Inventory Model

In order to have meaningful land use planning, accurate data on land uses are essential. In the United States, land use data have evolved gradually and piecemeal to meet specific needs. No comprehensive system of collection, analysis, publication, and retrieval of land use data has ever been developed. Federal, state, regional, county, and local governments collect and maintain data largely independent of each other. There is little uniformity of coordination in organizing and disseminating basic kinds of land use data among planning jurisdictions and little agreement and consistency concerning land use definitions and projection dates.

Because of the lack of land use data, there has been an absence of quantitative land use analysis. Methodological approaches already exist for the development of techniques to analyze land use data. The challenging step is to obtain and present needed data in a quantitative analysis format that will be comparable and useful to land use policy makers at national, state, region, and county levels.

Recent pilot land use research in Iowa has begun to respond to these needs for land use information by public agencies engaged in planning for the use, management, and development of Iowa's land resources (Gibson). Although this research has been limited to Iowa, the analytical methods seem applicable in other states.

The Iowa land use inventory model focuses on two general categories of land use—agricultural and nonagricultural—and their respective subsets of uses. Agricultural land uses are disaggregated by major crops, while nonagricultural land uses are disaggregated by subcategories. Both agricultural and nonagricultural land uses are analyzed in terms of extensive (acres) and intensive (density measures) use classifications within specified spatial units including incorporated place, county, multicounty planning region, and state.

To determine past and present land uses and to provide a data base for projections, relevant available land use data were obtained from state and federal government agencies and published data sources (see appendix A, part 7, in the *List of Agencies Contacted for Land Use Data,* Gibson). Also, mail surveys were used in obtaining land use data and information from Iowa incorporated places, county extension agents, and multicounty planning entities. Sampling techniques were used to make data adjustments. A multiple regression model was used to identify the major economic determinants affecting past and present demands for Iowa urban land uses.[7]

Land Use Projection Model

Land use research in Iowa has developed a model for projecting future nonagricultural and agricultural land uses under varying assumptions and alternative public policies. Initially, baseline projections were made for land uses expected to materialize if there are no demand, supply, or institutional changes of an unusual and unforeseen nature or magnitude in the causal factors that have been changing over time. The baseline projections provide these functions: an assessment of future land resource needs, an indicator of a potential land resource use problematic situation in terms of a divergence between future and desired land resource uses, and a framework for evaluating

[6] The U.S. Water Resources Council establishment of principles and standards for planning water and land resources is an example of an administrative order illustrating both clarity of wording and differentiation between means and goals.

[7] Urban land use includes nonagricultural land uses within Iowa incorporated places. Agricultural land within Iowa incorporated places is defined as land of ten acres or more that has not been planted and is preferentially taxed as agricultural land.

(*a*) alternative projections reflecting possible exogenous shocks and normative changes and (*b*) projections under public policy land use constraints as a measure of the effects of policy changes.

There are two general parts to the land use projection model—projected noncropland uses and projected cropland uses. With regard to the noncropland segment, regression analysis and trend extrapolations were used to project quantities (acres) of nonagricultural land resource uses (urban, highways, airports, public recreation, private recreation, and extractive land uses) and noncropland agricultural land resource uses (pasture, forest, and other land in farms). Projections of qualities of nonagricultural land absorption and noncropland agricultural land uses were made by extrapolations from the initial inventory data according to rules specific to the subcategory of land resource under consideration.[8]

With regard to the cropland segment of the land use projection model, the study evaluated the significance of U.S. Department of Agriculture OBERS crop requirement projections for Iowa (USDA and U.S. Dep. Commerce). OBERS (Office of Business Economics [U.S. Department of Commerce] and Economic Research Service [USDA]) projects Iowa crop requirements by using the state's historic contribution record as a basis for disaggregation. Iowa regional crop requirements were projected by allocating projected ranges of Iowa statewide crop requirements to each of the economic planning regions according to the region's historical percentage distribution. Given ranges of projections of future crop yields by land qualities within Iowa regions, projections of the acreage required for crop production were made. These projections were compared with projections of the supply of land services for cropland purposes (given projections of nonagricultural land absorption by quantities and qualities and noncropland agricultural land uses) to protect a surplus or deficit of regional cropland acres. Thus, the implied baseline norm for evaluating the land use projections of this model is that Iowa regions can continue to supply their historic trend contribution of U.S. crop requirements. These baseline projections provide a framework for evaluation purposes between this norm and the projected land use situation and alternative projections reflecting possible public policy changes.

Various ranges of assumptions of nonagricultural land use absorption and noncropland agricultural land use conversion to cropland uses were considered. The assumptions and policy shocks were introduced into the land use projection model in various combinations to estimate the sensitivity of changes in each exogenous land resource variable to the agricultural development potential, with respect to land constraints, within each region.

The Iowa land use research makes maximum use of secondary published data and primary data survey methodologies available to all states. The land use projection model provides an internally consistent set of regionalized land use projections for the state that are comprehensive in coverage of major land use classes and provide uniformity of base and projection target dates. The land use projection model is dynamic since different solutions can readily be computer derived under different policy programs. The land use projection model is consistent with the framework of national OBERS projections, which are periodically updated.

Utilization of Research Results

Empirical results of the multigoal land use model revealed the ranking and intensity of first, second, and third goal choices of respondents within a multicounty planning region (Lundeen). Results of this study indicate that land use planning can no longer be considered to be single purpose; multiple goals must be considered when constructing land use plans. Although citizens may not be able to participate in the technical aspects of land use planning, articulation of goals is one essential means for citizens to participate in land use planning. If citizens realize that technicians are directing land use planning toward their preferred goals, then they may be better motivated to execute the plans.

Systematic information on Iowa's past, present, and projected land resources would be a valuable input into the development of a land use policy for the state and aid county and multicounty planning entities and land use planning educational programs. Although many of the results of these pilot studies are more suggestive than definitive, some of the

[8] The 1967 Conservation Needs Inventory (CNI) data, available for all states, were used as the data source for land qualities (land capability classes) (USDA).

more salient statistical conclusions and projection model results are summarized. Policy implications are also indicated.

Research effort was devoted to developing a regionalized set of land absorption coefficients for Iowa (Gibson). Between 1960 and 1970, urban population density declined or Iowa incorporated-place urban area per capita increased for every population size class incorporated place and for every region considered. On a statewide average basis, urban land per capita increased from 0.26 to 0.28 acres per capita from 1960 to 1970. Derivation of urban land absorption coefficients revealed that Iowa's incorporated-place land absorption per capita is higher than the corn belt average and much higher than the national average. Iowa incorporated places of greater than 50,000 people were found to absorb more than double the land per employee compared with the national average, reflecting a relative surplus of Iowa land.[9] These land absorption trends provide valuable information in formulating future land use policy. For example, if zoning is to be effective in directing land use development, officials must recognize the amount of area that may be absorbed by various land uses.

An analysis was made of urban land absorption coefficients for different population size Iowa incorporated places. Iowa's average urban land absorption coefficients generally increased, moving from large population size classes of incorporated places to smaller population size classes of incorporated places. Per capita land absorption differentials between different population size classes of incorporated places have important policy implications. If population migration is at a turning point (Beale) in the long movement from rural to urban dwelling, then this could lead to significant increases in urban land absorption per capita.

Between 1960 and 1970, the amount of agricultural land within Iowa incorporated places increased 17% (63,000 acres); at the same time nonagricultural incorporated-place acres per capita increased. Growth in population of Iowa incorporated places was found to be associated with incorporated-place land annexation in spite of large amounts of agricultural land presently existing within Iowa incorporated places.[10] Between 1960 and 1970, less than 2% of all Iowa's incorporated places had an actual net decline in land area, indicating the apparent irreversible nature of the urban land use process, even though there is much agricultural land within Iowa incorporated places that is not physically urbanized.

The relatively large stocks of agricultural land within incorporated places in Iowa comprise a potential land resource of considerable value in terms of accommodating additional urban land use needs. Projections of future Iowa urban land use needs revealed enough existing agricultural land within Iowa incorporated places in 1970 to accommodate these needs for all sixteen of Iowa's economic regions to the year 1990 and for fourteen of the sixteen Iowa economic regions to the year 2000.[11]

The multiple regression study of urban growth in Iowa found that change in urban population explained 80% of the variation of change in urban land use (Gibson). Neither change in income nor change in average value of agricultural land and buildings explained much of the variation of change in urban land use. Over the ranges observed, demand for total new Iowa urban land implicitly seemed both price and income inelastic. A policy implication is that present prices of agricultural land in Iowa are not sufficiently high, relative to urban demand, to play any significant role in rationing agricultural land to urban uses.

Major conclusions of the Iowa land use projection model are summarized on a statewide basis as follows. Alternative projections of Iowa land use found that the public policy alternative of preserving highly productive Iowa cropland (corresponds to CNI land capability classes I to III) from nonagricultural land use conversion had a negligible (compared with similar baseline projections) effect on increasing Iowa's cropland resource

[9] This was found for both manufacturing and associated land uses per manufacturing employee and wholesale trade, retail trade, and services and associated land uses per wholesale trade, retail trade, and services employee.

[10] In 1970, there was 430,000 acres of agricultural land within Iowa incorporated places.

[11] These projections ignore any land quality constraints, such as slope and drainage, on the use of these lands for urban uses. However, twelve of the sixteen Iowa economic regions were each projected to have more than 1,000 remaining acres of agricultural land within incorporated places in the year 2000. These projections also ignore possible individual incorporated-place deviations between urban land use needs and agricultural land availability within the incorporated place. Projections at the county level found that seventy-eight of Iowa's ninety-nine counties could meet their projected future urban land use needs to the year 1990 by utilizing the amount of agricultural land existing within their incorporated places in 1970.

use capacity in the near-, medium-, or long-term given ranges of projected yields and crop requirements.[12] The differential regional impact of such a policy was also found to be small. An empirical investigation of a possible Iowa cropland resource capacity contingency demand was alternative projections of accelerated nonagricultural land absorption. Only for high trend crop requirements (high export assumptions) and low trend yields combination of projections in the long term did accelerated nonagricultural land absorption cause a deficit of Iowa statewide cropland acres from comparable baseline projections. The public benefits of prime cropland preservation in Iowa may be small in terms of significant increases in output of food and fiber. But this conclusion ignores other possible public benefits from prime cropland preservation, such as those associated with increased environmental quality and with option demand benefits resulting from uncertainty in both the supply and demand of future food and fibers.

The public policy alternative of improving the quality of the environment by removing fragile Iowa cropland (corresponds to CNI land capability classes IV to VIII) from production did not place undue stress on the general productive capacity of Iowa statewide cropland, except in the long term under high-trend crop requirements and low-trend yields combination of projections. Not all regions in Iowa were affected equally by such a policy. Public costs of removing private Iowa fragile lands from production must be measured against the public benefits of such a policy, taking account of regional distributions of costs and benefits.

Further Land Use Research Needs

The Iowa land use research has been more of a reconnaissance survey than a definitive analysis. Further land use research needs, summarized below, will be incorporated into ongoing Iowa land use research.

With regard to the multigoal land use model, information is needed on the technical relationships between means and goals of the model. For example, an acre of land used for industry may contribute to achieving environmental quality, economic development, or social well-being. With these coefficients and weightings of land use goals, a multiobjective goal program could be developed.

Analysis is needed on land use interrelationships among different population size classes of incorporated places and spatial regions. The following kinds of questions need answers. Do different population size classes of incorporated places have different per capita and per employee land absorption relationships? How is this related to urban hierarchies? Why do incorporated places continue annexing agricultural land when there is ample existing land already within them? Is this a means whereby the incorporated place can gain future control over these land uses through development regulations? By annexing new land is the incorporated place gaining a higher proportion of middle income residences, thereby alleviating fiscal difficulties but creating land use inefficiences? Do annexation laws overly encourage substantial agricultural land annexation? Do preferential tax laws lead to a premature incorporation of agricultural land because agricultural land within the city perimeter is taxed more favorably than the same agricultural land just outside the city limits? Do speculative expectations of increased land values within incorporated places promote annexation? What are the forces behind the supply decisions of land owners that influence the pattern of urban development? Is nonagricultural land use just outside incorporated places taxed more favorably than nonagricultural land just inside incorporated places, and does this lead to urban sprawl? How do public investments influence land use shifts particularly in rural-urban fringe areas? In general, more information needs to be known about the forces behind the land-transfer process before effective land use policy tools can be developed to control land use.

Research is needed on economic decision rules that incorporate social risk aversion, interdependent decisions, and irreversibilities. These rules could be incorporated in cost-benefit analysis to evaluate the decision to preserve "prime" agricultural land.

What are the implications of the effectiveness and economics of land use approaches rather than structural or technological abatement techniques in controlling agricultural pollution?

Alternative land use projections based on

[12] Land use projections for the years 1980, 2000, and 2020 can be considered near-, medium-, and long-term projections, respectively. These projection dates correspond to those used by the U.S. Department of Commerce in making economic projections (USDA and U.S. Dep. Commerce).

alternative methodologies should be made and compared. Projecting different land uses over the long run is not susceptible to any single method or model. Probably more can be learned from accommodating differing projections based on different approaches, premises, and data, as from sequential manipulations of a single method undertaken independently.

Finally, much investigative study needs to be undertaken in the area of land use policy tools. This research should be closely coordinated with land use goals derivation because policy tools become meaningless without valid objectives to achieve. Selection of policy tools should be analyzed in terms of the objective function derived and the needs and characteristics of the region under consideration.

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Prime Lands—Definition and Policy Problems

William W. Wood, Jr.

> The preservation of agricultural land is of paramount interest to the welfare of the state of California in that the preservation of such land, especially prime agricultural land, is critically important in order to assure and to maximize the food, fiber, open space and employment opportunities which are necessary for present and future generations of the state and the nation.
>
> Warren (section 67701)

As a proposed policy statement authored by an urban legislator, this quotation from proposed California Assembly Bill 15 seems to epitomize the increasingly popular cry to save or preserve prime agricultural land. Since prime connotates first in importance in terms of quality or value, intuitive support of such cries seems most appropriate.

Mature reflection suggests that efforts to save prime agricultural land must mean that market allocation is not achieving the objectives of such observers. This being the case, a substitute for market allocation must be developed, the assumption on which this paper is presented. The alternative is a public policy capable of implementation to insure that a specific resource such as prime agricultural land will be utilized so as to accomplish stated objectives. Simply stating as public policy that we shall save or preserve prime agricultural land is not capable of implementation; a positive action policy must be identified with specific applicability. At this juncture some very serious definitional difficulties as well as policy conflicts arise. Simply stated, prime in a nebulous sense may be universally acceptable; prime in a specific policy implementation sense no longer is as universally acceptable and in fact may not be acceptable to anything approaching a majority position.

The basic policy problem involved in the issue of prime lands centers on the inability or unwillingness to separate the scientific classification function from the policy-making function. If the word agriculture consistently follows prime, then it may be scientifically possible to define prime agricultural lands, i.e., those most appropriate for the production of agricultural commodities, and ignore the more generic definition of prime lands. Simply to define lands as prime, as in fact a number of scientists as well as urban observers tend to do, avoids the fact that land prime for agriculture is likewise apt to be prime for other societal uses. Thus, the scientific responsibility is to identify and analyze as many of the alternatives as can be found, while the policy-making responsibility is to select alternatives for specific parcels of land. Even with regard to agricultural land, however, we may have fallen into the trap of confusing classification or taxonomic approaches with policy making (Wood, p. 151).

Definitional Criteria

There appears to be an implicit assumption on the part of many observers that, given the objective of preserving prime agricultural land, the criteria for defining such land are objectively identifiable and capable of uniform application. Unfortunately, this implied assumption seems to lead full circle in that the selection of appropriate criteria depends upon the definition of prime, which in turn depends upon the criteria selected. The development of soil classification criteria has been a matter of interest and attention on the part of soil scientists and perhaps agronomists. Fenton gives an excellent and concise review of the development of land classification systems in the United States. The development of criteria for definitions of prime agricultural land now involves not only soil scientists but also economists, planners, engineers, and, for that matter, the general public. As a result, there is no longer an easy consensus as to what the

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objective may be with regard to a classification system (House, pp. 2–3).

This expansion of interest is a relatively recent and continuing matter. For example, the *LIM Task Force Report* in November 1974 listed nine criteria (see Fenton) for prime agricultural land relating exclusively to soil-water-topographical characteristics (USDA 1974). In an unpublished preliminary draft of a potential cropland study by the Soil Conservation Service (SCS) in May 1976, additional characteristics were included such as the size of ownership unit, the size of tracts, and the extent to which the area was isolated (USDA 1976a). Even Fenton recognizes that energy utilization and its relationship to productivity may be an important consideration in soil classification (p. 142).

The technical criteria as used in the Land Inventory and Monitoring System (LIM) provide either a range of values within or a specific value above or below which land will qualify as prime. Once so classified, the applicable value for that variable is lost for future policy decisions; the system is completely static. For example, a pH between 4.5 and 8.4 in the appropriate zone will qualify. However, in many agricultural operations over time, there may be significant differences between soil that has a 4.6 pH and that with an 8.3 pH. The same lack of specification will apply to moisture, temperature, conductivity, erodibility, permeability, and texture. Unless measurements made for site-specific classification are stored in a retrievable manner, aggregate designation as prime precludes flexibility for future decisions.

Another serious definitional problem evolves from the use of the word agriculture. From a public policy standpoint most observers are concerned with either agricultural products or perhaps more specifically food and fiber. Pragmatically, however, land is not used to produce food and fiber but rather to produce crops that have different characteristics; these may depend upon whether the perspective is that of a market economist, a nutritionist, or a social psychologist. With several hundred commodities involved, it is obvious that agriculture is not homogeneous in this respect.

Futhermore, different commodities require a wide range of characteristics in terms of soil, climate, and other conditions for effective production. Thus, a particular classification of land that is appropriate for the production of corn or soybeans may not be as appropriate for the production of rice or cotton. As a result, a national definition of prime agricultural land assumes some relationship to appropriate commodity production. Thus, land appropriate for the production of avocados in Southern California or blueberries in New England is presumed to be less significant to a national interest than is land for the production of corn in Iowa. While this may ultimately be the case, it is not at all clear that the classification effort for prime agricultural land is licensed to make policy decisions as to which commodities should make up the total food supply. This would infer priorities in terms of continued commodity availability.

A basic economic contradiction arises. If one accepts the assumption that market allocation of land does not meet societal objectives for future food supply, dependence upon market allocation of commodities does not appear consistent. Ultimately nonmarket, i.e., public policy, allocations of commodities (food), and other land-oriented economic activities, would be a natural consequence.

Calories, Commodities, and Climate

A definition of criteria for prime agricultural land either assumes the inclusion of a variable relating to flexibility—the ability of a given parcel of land to be utilized for the production of a large number of differing commodities—or that some other prioritization system has been utilized. Such a system might well be the number of calories provided for human consumption, or it might be some measure of the net additional energy produced over the energy required in the production process itself. In fact, one senses an increasing urban concern toward reserving commodity production for those in which caloric content of the final product for human consumption exceeds the caloric input in the production process. This is particularly true for energy from fossil fuels. This consideration has led many areas to seriously examine their position with regard to continuing food supply. The Commonwealth of Massachusetts, for example, has developed a report entitled "Policy for Food and Agriculture," which attempts to deal with a number of policy issues (Congressional Record, pp. S.589–91). Included in this document is a recommendation for identification and mapping of prime farm land. From a defin-

itional standpoint the question arises as to whether Massachusetts' prime farm land is the same as that envisioned for a U.S. definition under more general criteria.

Relativity and Local Interest

Definitions of prime, by their very nature, are relative to some defined population. Prime from the standpoint of the total United States is apt to be considerably different than prime from the standpoint of the Commonwealth of Massachusetts or from the standpoint of a country or local community (although this difference is entirely ignored in the Secretary's Memorandum No. 1827, Supplement 1 [USDA 1976b]). The Government Code, State of California, defines prime lands for purposes of California. Land may be classified prime by meeting any one of five categories. Three of those categories are technical in nature.[1] However, two of the classifications for prime land are economic, i.e. "land which has returned from the production of unprocessed agricultural plant products an annual gross value of not less than $200 per acre for three of the previous five years" (chap. 7, art. 1, sec. 51201). From a policy standpoint California presumably considers the economic contribution of agriculture as significant a factor as the technical definition of land categories that are able to produce food and fiber over time.[2] A definition of prime land such as contained in the LIM project for the United States is not apt to be completely satisfactory for those states and/or communities that have other objectives in mind with regard to prime farm land preservation.

Much of the urban support for prime agricultural land preservation may well stem from quite different factors than those that more traditional agricultural analysts examine. Recent increases in retail food prices may be a triggering mechanism. However, factors such as open space, aesthetic appearance, environmental quality, and romantic notions seem implicit, particularly if achieved with minimal urban cost. The appeal of cattle grazing near residential areas may convert even marginal land into prime in the minds of urban residents. The agricultural findings and policies of the *California Coastal Plan* recommend preservation of thousands of acres on the basis of its importance to agriculture, although such land is marginal in terms of animal carrying capacity and certainly not "prime" on any productivity rating (California Coastal Zone Conservation Commission).

A further conflict exists relating solely to land that may be technically class I under the SCS classification system but located in an urban area. As Peterson and Yampolsky observe, land in an urban area may be technically capable of agricultural production but be incompatible for practical purposes due to a variety of social, environmental, legal, and economic reasons (pp. 13–15). This suggests the need for including definitional criteria beyond those presently utilized.

Alternative Approaches

One alternative under consideration is to rely upon what amounts to a semantic cop-out. This alternative would simply eliminate the use of the word prime in any of the definitional approaches to land classification and rely on some substitute word that would not have some of the connotations currently attributed to the word prime.[3] Unfortunately, this does not solve the dilemma of classifying land areas that are of critical long-run national or local concern; it remains static. The primary reasons are a failure to distinguish among identification, analysis, and classification (essentially scientific responsibilities), policy making (essentially allocative), and persistent inflexibility. While the word prime may well be one source of the present dilemma, criteria rather than names are at issue.

A second alternative is to rely on the technique currently used in the LIM project of identifying a prime land definition on technical criteria and relegating other significant portions of land area that are important for commodity production to a classification called unique. Two difficulties arise with this approach. The first is that since unique has no objective criteria, the inclusion of any land in this category is a policy decision. If such in-

[1] These technical categories include classes I and II under the SCS Soil Classification System, 80 to 100 under the Storie Index, and one animal unit carrying capacity per acre.

[2] An interesting contradiction in that market allocations of commodities are used to provide a basis for replacing the market in the allocation of the major production input, land.

[3] For example, there was a tentative proposal in the 1976 Session of the California Legislature to substitute "commercial" for "prime."

clusion is specified by those developing classification and criteria measurement, the scientific and policy-making roles are intermixed. The second difficulty is the psychological impact, particularly on citizens of communities and regions, of having their farm land excluded from prime. While unique may have positive psychological values, these tend to diminish as awareness rises that any land not in the prime category is eligible for unique. Furthermore, under this system inclusion of specific criteria for prime implies that commodity and/or caloric priorities have been included.

A third alternative explicitly recognizes the separation of scientific analysis from policy decisions and attempts to set up a series of criteria by which land may be classified (Wood). Under this proposed system any parcel of land can be evaluated for all significant variables, perhaps as many as twenty or twenty-five, and given a cardinal number on a scale of zero to ten in such a manner that the values for each variable are additive.[4] If the total possible points from all variables is, say, 200, then the policy maker is in a position to define prime agricultural land as that land with a rating of over a given number such as 150 or 175.

A further advantage of this system is that with the use of computer sciences, a program can evolve in which particular values for any given variable can be specified in order to identify the amount of land that is capable of producing a given commodity with very specific requirements. A quite common cry in California, for example, is that prime agricultural land must be preserved in order to guarantee continued production of brussels sprouts; this production is limited to a very small portion of two counties on the California coast. Most of the land involved in such production is not technically prime land under current classification systems, except as it qualifies under the economic category in the California definition. However, under a matrix analysis if one or two variables such as temperature extremes or hours of sunlight and cooling fog are particularly significant, identification of that land susceptible to the production of brussels sprouts could quite easily be identified.

This classification system allows flexibility. Since specific values for each variable are retained, changes for any parcel can be made as circumstances alter. Changes in water availability, adjacent land uses, or technology can be instantly included to reflect current conditions. Thus, the system does not become outdated for policy purposes. In this manner, the classification system shifts from completely static to partially dynamic.

As suggested above, the waters have been muddied considerably in the matter of attempting to define and inventory prime farm land or prime agricultural land in the United States. This confusion arises from a number of sources: the multidisciplinary perceptions of prime, the confusion between taxonomy and policy making, and perhaps most importantly the fact that local and national objectives do not completely coincide. The seminar conducted by the U.S. Department of Agriculture at Airlie House in July 1975 was an exceptional step in attempting to reconcile the problems with productive agricultural land in the United States. Unfortunately, for a variety of reasons the follow-through from that seminar seems not to have been as productive as might have been hoped.

Not only are there institutional factors involved, but also vested interests on a geographic, political, and even professional basis. The nonmarket allocation of productive lands for future food and fiber supplies cannot be accomplished by either agricultural economists or soil scientists working in isolation. Furthermore, if a national definition of land classifications is the approach that seems politically feasible, then it seems appropriate for that definition to be sufficiently flexible to permit state and local entities to interpret within guidelines established at the national level.

At present, California, for example, is using some of the traditional national definitions with some expansion. My concern is that California, in its infinite (or infinitesimal, as the case may be) wisdom, may decide that national guidelines and definitions for prime agricultural land are not sufficiently applicable and develop its own system as has so frequently happened in public policy in the past. The same sort of danger exists with regard to many areas of the United States with the possible exception of the Corn Belt, for which the

[4] For additive purposes, undesirable variables can be ranked on an inverse scale of ten to zero. Subjective variables, on an ordinal scale, can be converted to cardinal numbers while cardinal values, pH, for example, can be included directly. In addition, proximity to urban services with excess capacity or other nonagricultural variables can be included.

current approach to prime land definitions seems most appropriate.

As commonly used, prime seems also to be a function of time. A static definition will not pertain under all future conditions. Changing conditions—population, technology, and weather—very likely will alter criteria for selecting optimum land allocations.

Conclusion and Recommendation

It seems appropriate for representatives of the legislative branches of government to call for preserving prime farm land; it may also be appropriate for top level members of the executive branches of government. However, it is not appropriate and in fact counterproductive for similar appeals from the scientific community without clearly delineated criteria for definitional purposes. Therefore, much of the energy and resources currently devoted to advocacy should be redirected to developing a land classification system useful to policy makers. Such a system cannot be solely technical—from soil science and agronomy—but must also include aesthetic, economic, environmental, and social variables. With such a system, the extramarket land allocation decisions can be made if politically feasible.

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Rural Development, Poverty, and Regional Growth
(Eldon Smith, University of Kentucky, Chairman)

The Political Economy of Rural Development: Theoretical Perspectives

Clark Edwards

The rural and urban sectors of the economy are strongly interlinked. Growth in one sector impacts on the other. The growth process does not appear to be an equilibrium one in which marginal adjustments to opportunity costs eliminate disparities. The two sectors grow in an unbalanced way. So far, the economic advantages appear to have favored the urban sector.

The income gap between the rural and urban sectors continues to widen; rural income per capita is around three-fourths of urban income. The incidence of rural poverty is twice as high as urban poverty. Rural people have relatively limited access to health facilities, they are more likely than urban dwellers to live in substandard housing, and they attain lower levels of education.

Some conditions in the rural sector have improved recently relative to earlier decades as well as relative to the urban sector. Between World War II and 1970 rural to urban migration flourished, but since 1970 it appears to have reversed direction. Even so, the symptoms of imbalance continue. In a number of rural counties, social and economic opportunities are limited and outmigration continues.

This rural-urban imbalance is of national concern. It appears to have resulted in relatively densely populated cities and sparsely populated countryside. Rural development can increase economic efficiency, add to the nation's goods and services, and enhance the social and economic well-being of both the rural and the urban sectors.

A need has been felt by society to do something as a nation to improve the social and economic well-being of rural people. Some actions aim at improving efficiency and increasing aggregate well-being; others aim at equity and improving the distribution of income. Frequently, it is assumed that accelerating rural growth will, as a side effect, alleviate rural poverty. Empirical evidence raises doubts about this assumption.

A correct theory is not essential to problem solving. For example, 3,000 years ago, long before the laws governing motion in our solar system were sought, the Babylonians accurately predicted the apparent motions of stars and planets and knew when to expect an eclipse. Later, "incorrect" theories, in which it was assumed the sun is in orbit around a stationary earth, did not interfere with the accuracy of celestial forecasts. Now we have the "correct" theory, which jointly explains celestial motion and terrestrial tides. But the tide tables appearing in our daily newspapers continue to make no use of this theory. The rise and fall of tides is still predicted by empirical methods *sans* theory. No, a correct theory is not essential to describe and forecast events. This explains why so many people have accomplished so much of value in rural development while claiming that there is not an adequate growth theory.

But theory helps if we seek to understand events or to influence their outcome. We need to probe deeper into theories of change if we expect to understand the rural development problem and to seek public and private policies to ameliorate it. We have several growth theories, all of them partial, most of them helpful, but none complete. Together, they cast considerable light on rural development and can serve as guides to formulation of public policy.

Temporal and geographic variations in population, income, and employment have been

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explained in a number of ways. Some explanations, upon examination, turn out instead to be descriptions of history. Other explanations assert that everything in the economic system is functionally interrelated and that one must analyze the total system before one can begin to understand how it grows.

This paper is organized around five key factors that have each been considered in economic literature as the basis for regional growth. Public and private programs and policies are in place that influence each basis. The five alternative bases for growth are increasing resource availabilities, advancing technology, expanding markets, conquering space, and building institutions. A considerable portion of the literature on economic development refers to none of these bases; such literature is descriptive rather than analytic. For example, the "stages of growth" literature describes growth over time, while the "diffusion" literature describes cross-sectional patterns of geographic change. Occasionally, an author will be found who discusses several, or possibly all, of the five bases for growth. In such cases, there is a tendency to consider only one of the five as "basic." When an author considers two or more of these five bases equally, we may classify that theory as a "systems approach."

Increasing Resource Availabilities

More input induces more output. Classical and neoclassical theories explain regional variations in growth by regional availability of land, labor, and/or capital. If there is a single most popular basis for growth in the literature of economics, beginning with Ricardo, surely it is the accumulation of capital. The theories of Harrod and of Domar treat capital accumulation as the key. Romans notes that, "from colonial times to the present day, statesmen and economists have assumed interregional capital movements to be a major variable affecting the economic growth and welfare of regions in the United States" (p. 3). Hirschman discusses many factors influencing growth but funnels them all through "the ability to invest" (p. 177).

There is a chicken-and-egg argument in the literature as to which is cause and which is effect in economic development—public or private capital. Hirschman favors a relative scarcity of public capital. Others argue that public capital in the form of schools, roads, hospitals, sewer and water, and industrial parks is causal.

Natural resources have been seen as a limit to growth since Malthus suggested that population is limited by the capacity to produce food. Ricardo viewed the supply of land as perfectly inelastic. Later, Turner attributed rapid growth in the United States to the availability of cheap land on the frontier. The modern view is that increased services from natural resources can be made available through applications of capital. Perloff and Wingo relate regional availability of natural resources to what they call "the geography of national economic expansion" (p. 191). They trace the role of deep water ports and agricultural hinterlands in the early agricultural period, of minerals during our industrial expansion, and of amenities of climate, land, coastline, and water during the "services" era.

Growth in population was seen by Smith as a stimulant to the wealth of nations. Now we find two views toward the role of population in economic growth. Hirschman, following Smith, says that more people add to both the incentive to consume and the capacity to produce, while Schumpeter says that more people may mean more mouths to feed and a reduced level of living. Migration tends to override the effects of natural population increase in regional growth. As with population, one finds two views: inmigration adds to the size of markets as well as the capacity to produce or inmigration is a burden adding to congestion and welfare rolls. Labor force participation tends to be smaller in slower-growing regions; growth depends on the proportion of the region's population at work. The quality of the labor force is as important as quantity.

The policy implication of neoclassical growth theory is: to develop rural America, we need to provide it with more resources. Rural development programs frequently emphasize capital. For example, the model implicit in the Rural Development Act of 1972 is: outmigration would be stopped, or even reversed, if more jobs were created; jobs are created if output is increased; and output is increased if plant and equipment are expanded. Therefore, supply rural areas with more public and private capital. Tax incentives and low interest guaranteed loans to plants locating in rural areas are further examples of capital accumulation policies.

The Departments of Agriculture and Interior operate natural resource development programs that increase the availability of energy, minerals, water, and agricultural land. Friedmann noted that, "until the late 1950's, most people understood regional planning to mean the purposeful development of a region's natural resources" (p. 792), a view much narrower than is held today.

The recent emphasis of public and private population programs has been one of limiting birth rates. The Labor Department recently revived its experimental program to relocate people from areas of limited economic opportunity to areas with greater prospects. Labor force expansion programs equip people with specific job skills and/or with freedom to join the labor force.

Advancing Technology

Advancement through science and innovation is probably the most widely held basis for growth outside of economics, that is, among historians, philosophers, scientists, anthropologists, and others. The idea is also one of the oldest. In Sophocles' *Antigone*, the chorus comments that man has always helped himself and faces no future helplessly. He has learned to cross the sea in a winter storm, to plow the fields with mules, to snare birds, net beasts and fish, ride horses, provide shelter from cold and rain, and has even taught himself a language. Each of these advances led to an increase in the availability of things valued by man per unit of input.

Among modern economists, technology follows resource availabilities as the most often cited basis for growth. As Leven put it, "the driving force behind economic growth is productivity" (p. 80). Kuznets asserts "modern economic growth is distinguished by the fact that the rise in per capita product was due primarily to improvements in *quality*, not quantity, of inputs" (p. 491). Schumpeter said "development consists primarily in employing existing resources in a different way, in doing new things with them" (p. 68).

Technological advance concerns the productivity of labor as well as capital. Kunkel sees human development and the analysis of behavior as the basis for social change and economic growth. Schultz finds "a strong connection between the investment in human capital and the secular rise in the economic value of man" (p. 1113). Much of economic growth, says Schultz, cannot be explained by additional inputs of conventional types.

The policy implication of advancing technology as a basis for growth was illustrated during the 1960s by extensive public and private efforts to modernize rural plants, provide on-the-job training, reduce underemployment, and improve productivity. These efforts were abetted by federal programs to provide orientation, counseling, education, skill training, and other services to help qualify individuals. Productivity gains in the nonmetropolitan sector during the 1960s were greater than in the metropolitan sector, which helps explain the recent surge in rural growth.

Expanding Markets

Expanding the market for products of a region as a basis for growth has been traced by Spengler at least back to the mercantilists. The idea has been suitably captured in the following quote from a presidential advisory commission: "The ability of a community to grow depends upon its success in attracting additional spending within its confines—whether this be personal consumption, business investment, or government outlays" (Advisory Commission on Intergovernmental Relations, p. 37). The commission might well have added "net exports." Expanding rural markets may include exports to abroad, such as wheat to Russia; shipments to urban areas, such as textiles; or local consumption. Each region can grow while the nation as a whole grows.

Alternatively, emphasis may be on expanding the derived demand for local resources by, for example, industry location. This view is frequently coupled with the notion that regional growth is a zero-sum game; growth in one region must be at the expense of another. Such thinking leads to antipirating clauses in rural development legislation.

The idea that nations or regions can mutually gain through exchange was developed by Ricardo and by Mill. Comparative advantage, which is based not only on markets but also on internal resource availabilities, technology, and economic structure, implies that two trading regions can produce a greater total product than if there was no trade.

The potential for economic gain through international or regional trade can be exploited by residents of one region, at the expense of other regions, through increased exports or reduced imports. Economic base theory is a popular version of this narrow view. Growth is explained in terms of the market for a region's main export or staple. Total employment is allocated between base industries, in which the product is destined for export, and nonbase residentiary industries, in which the product is destined for local use. The critical assumption is that residentiary employment is a function of base employment. It follows that total employment grows as base jobs are created through expansion of net exports. Greenhut argues that the unfortunate and widespread belief that export base is extremely important has helped promote abandonment of classical economic principles. He finds the internal structure of a region important and calls for "a return to the classics" (p. 461).

Keynes revived the idea of Malthus and others that aggregate demand is the basis for growth. He recognized both internal and external sources. Keynes was concerned with the short run. He asserted that at full employment his general theory is the same as neoclassical theory. Short-term growth of a partially idle economy may depend on expanding aggregate demand, as Keynes suggests, but long-term growth may depend on expanding capacity. This view was expressed by Borts: "Over long periods of time, it appears that the demand hypothesis does not play a role in explaining regional economic growth . . . supply factors appeared to have been very important in explaining regional growth differentials" (p. 133).

Expanding aggregate demand is a vague and general notion; some theorists, such as Rostow, demand more precision and seek to locate the origin of growth in a single sector. This turns attention toward a leading industry. Perroux emphasized that some industries are driving forces in an economy; the type of industry varies from region to region. This agrees with the views of Hirschman and Myrdal that growth is inherently not balanced. Some elements necessarily change prior to others and in different proportions. These disequilibrium views raise concern for conflicts between efficiency and equity.

The policy implication of market expansion as a basis for growth is illustrated by federal programs to increase or maintain exports to abroad. Many commodities benefiting from these programs are produced in rural areas. Increased government purchases or reduced taxes are frequently justified, in part, by their contribution to aggregate demand. State and local product promotion in the United States tends to be operated at the state or local level. Most market expansion programs are in the private rather than public sector.

Conquering Space

Geographic space has been overlooked as a dimension of economic space in much of economic theory. This was so even though Smith and Ricardo recognized the importance of location in their rent theories, and Von Thunen developed his seminal approach to location of economic activity some century and a half ago. During the last three decades, spatial relationships have been incorporated in economic analyses and are seen by some as the basis for growth. Richardson observed, "Growth rates vary with location . . . because the relative strength of agglomeration and dispersion factors alters over space" (p. 2).

Integration of location theory with the conventional theory of the firm leads to the conclusion that equilibrium in the space economy requires that marginal cost equals marginal revenue in spatial as well as nonspatial dimensions. Uncertainty tends to send plants to the obvious or safe location—the center of the market. Webber shows that this may result in concentrated patterns that would be suboptimal under perfect knowledge. From society's point of view, the profit-maximizing location of a plant need not be optimal with respect to, for example, providing jobs to residents of a slower-growing region.

Von Thunen had in mind a central place with agricultural hinterlands and was concerned with the spatial pattern of a region. Weber emphasized the importance of agglomeration. Christaller's central place theory incorporated the idea that the growth of a city depends on specialization in various functions and on the demand of the region it serves. Losch studied spatial relationships for noncompetitive markets and extended the analysis to general location patterns and the network of economic regions.

The central place provides jobs, shopping, and cultural attractions to residents of the entire region. The hinterland, on the other hand, provides rural-oriented goods, such as food, textiles, minerals, and timber products. It also provides workers to fill central place jobs and may provide residential and recreational sites and sites for decentralization of central place activities. The economic fortunes of a region depend on the interplay between its central place and hinterland as well as on its relationships with other regions.

The theories of Von Thunen, Weber, Christaller, Losch, and others suggest that a nation can be delineated into a number of regions, each with a central place and a hinterland. A hierarchy is formed in which some regions are fairly urban in character and provide central city services to others. Some regions are fairly rural in character and perform hinterland functions for the more urban-oriented regions. Commuting and trade patterns suggest that the United States is probably comprised of some 500 functional economic areas that are relatively closed with respect to trading and commuting. About half of these contain cities larger than 50,000 persons; the other half are relatively rural.

Prospects for development of a particular rural area depend in part on where it is located. A rural community in the hinterland of an urban-oriented region has different prospects for growth than a community in an isolated, rural-oriented region. Alonso suggests that "the path of fastest economic growth may imply sharp geographic inequalities concentrating wealth and power in a few advanced centers and condemning backward areas to lengthy periods of poverty" (p. 2).

The policy implication of spatial relationships as a basis for growth is illustrated by multicounty programs and by growth center strategies. Substate planning and development districts have been delineated for 527 districts in forty-five states for the purpose of coordinating federal programs. Other multicounty efforts, some of which are coterminous with substate planning and development districts, include councils of governments, economic development districts, resource conservation and development districts, and nonmetropolitan districts funded by the Department of Housing and Urban Development.

A number of federal programs, particularly those operated through the Economic Development Administration, accounted for spatial relationships through growth centers. The concept of a growth center is not so clearly defined as that of central place. Some authors apparently use the term to mean any urban place that grew recently. Hansen associates growth centers with places in excess of 250,000 persons. The Economic Development Administration's programs recognized smaller centers and were based on the theory that "accelerating the creation of employment opportunities in or near such centers was believed the most effective and timely approach to providing jobs for residents of neighboring depressed areas" (U.S. Dep. Commerce, p. 10). This became popularly known as the "trickle-down" theory.

The U.S. Department of Agriculture inverted this theory when it encouraged plant location in the hinterlands. Weitzell explains: "The basic theory underlying these . . . efforts is that rural industry can bring about sufficient economic growth to resolve problems of unemployment, underemployment, and low income. . . . the growth center concept should not be overemphasized. . . . modern communication and transportation . . . make decentralized development entirely practical" (p. 6). In contrast to the Economic Development Administration's trickle-down approach, this seems to imply that beneficial effects would trickle up.

The multipliers in the above approaches are variable and not too reliable according to subsequent evaluations by Milkman, Stewart and Benson, and Lewis and Prescott. Beneficial effects claimed from both the trickle-down and trickle-up theories have not been substantiated as a general rule. Programs aimed directly at a target group appear more likely to succeed than those that seek to accomplish their ends indirectly through a multiplier effect. An explanation of how to conquer space will likely never be arrived at by reducing spatial theory to simple multiplier relationships. The problems of communication and transportation over space, and their contributions to growth, are proving to be more complicated than that.

Federal programs to enhance transportation have had considerable impact on rural development. Interstate highways have frequently been cited as a prime example, but we must not overlook programs related to air, rail, and water transportation. Highway development policies have been associated with the rapid

suburbanization of major cities and concurrent depopulation of both the central cities and the more distant countryside.

Building Institutions

Man is a goal-oriented animal. He may seek to reach his goals as an individual or as a member of a group. A group of individuals organized to attain a goal has been described as an institution. Institutional arrangements can affect economic development.

In neoclassical theory, institutional arrangements to organize firms and households are assumed to evolve as needed to absorb increased demand, accumulate resources, innovate, and conquer space as firms and families take appropriate actions to reach individual goals in the growing economy. Samuelson has shown that this view implies that man need concentrate only on private firm and household goals; the free market will automatically organize firms and households into an efficient, equitable economy.

Contrary to the view that requisite institutions will always materialize as needed is Baran's view that "economic development has always meant a far-reaching transformation of society's economic, social, and political structure of the dominant organization of production, distribution and consumption" (p. 3). Authors with a relatively long-term view tend to pay far more attention to institutional change than those taking a short-term view. Perhaps this is because the pace of change in institutions is relatively slow and the impact negligible over shorter time periods.

North and Thomas find "efficient organization is the key to growth" (p. 1). They discuss the institutional change involved in the delivery of public goods, such as justice and protection; growth of the money economy; transactions; specialization; and, particularly, institutions related to private property rights.

There are several situations in which purposive institution building may be required to produce desired economic development.

(*a*) A competitive equilibrium situation may be held to be inequitable. An example may be taken from Keynesian economics where institutions are created to intervene with fiscal and monetary policies.

(*b*) The economy may not be converging on an equilibrium but may be observed, in fact, to be diverging. Myrdal identified what he called the principle of circular and cumulative causation as a cause of inequity, with the rich getting richer and the poor getting poorer. Institutions may be built to guide or redirect various strands of the economy toward a socially acceptable balance among diverging sectors.

(*c*) Monopoly power may override competitive forces. Antitrust legislation is an example of institution building to express dissatisfaction with the invisible, guiding hand.

(*d*) Uncertainty, or imperfect knowledge, may interfere with competitive choice. Schmid sees a relationship between insitutions and uncertainty. He states a need for research on how institutions might perform a hedging function. Imperfect knowledge creates the need for institutions for research, education, extension, market news, and insurance.

(*e*) Market failure may occur for public goods, goods that are consumed jointly by two or more users. Buchanan has shown that the rules for optimizing behavior are different for public goods than for private goods. Institutions required to deliver services of public goods, such as hospitals, roads, and symphony orchestras, need not evolve spontaneously, as market institutions for private goods do; sometimes they must be built purposively. Interjurisdictional conflicts among local governments are symptomatic of the institutional breakdown associated with market failure.

(*f*) Not all conflict is resolved in the market. Roboch describes how nonmarket institutions may cope with conflict and promote regional growth. Neale points out that goals of acquiring and exercising power came into conflict with economic goals in India. Ladd cites a conflict between parochial and cosmopolitan goals in Connecticut. Okano discusses conflicts between indigenous residents of a region and newcomers. Strong outlines a conflict between landowners along the banks of Brandywine Creek, who stood to gain from economic development, and residents of nearby townships, who preferred the status quo.

Policy implications of institution building as a basis for growth can be classed into two groups: those that facilitate other bases for growth discussed above and those that serve vital functions independently of those bases. Examples in the former category include financial institutions to provide capital, manpower training institutions to increase productivity, news services to expand markets, and zoning regulations to control spatial activity.

Other programs have resulted in formation of institutions for regional planning, identification of local leadership, and establishment and valuation of local ends. These institutions promote multicounty organizations and employ local coordinators to work with lay leaders in establishing priority needs and carrying out plans for community development. There is an emphasis on institution building to deliver public goods, such as health and education, to rural areas.

Conclusion

Five theoretical bases for growth have been considered. Policies for which laws and appropriations exist and which are directed toward each of the several bases, thereby influencing regional growth and rural-urban balance, were noted. The question is: if we know the bases for growth, and if we already have policies acting on each basis, why do the problems persist?

Economic theorists have not integrated the five bases conceptually. In fact, defenders of one basis frequently skirmish with defenders of others as to which favorite is really the key to growth. The neoclassical marginalists, the Keynesians, the regionalists, and the institutionalists continue to regard one another as misguided.

Policy makers have not waited for a fully developed growth theory before implementing programs that influence growth, evidence that a correct theory is not essential to problem solving. However, they have failed to integrate their several policies.

Most government programs that have impact on regional growth and rural-urban balance are created and operated with other ends in view. Adverse side effects on the rural economy may go unnoticed because such effects were not the purpose of the program. Noticed or not, the effects occur; government programs can unwittingly contribute to the problem.

Government programs that are explicitly focused on rural development tend to be fragmented rather than integrated. With each agency operating such programs, single purpose thrusts are focused on specific targets. Such targets may be met, but it may not be the responsibility of the persons involved to be aware of unintended side effects.

Economic theorists need to look again at theories that explain change over time and space. They need to provide policy makers with a more clear understanding of the disparate effects of policies. Policy makers need to be more clear about rural development goals and about the impacts of existing and proposed legislation and appropriations that act on the several bases for growth.

We have the theoretical and practical potential to develop rural areas and achieve rural-urban balance, but we have not yet learned to put it together.

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Rural Development Research: Conceptualizing and Measuring Key Concepts

J. Dean Jansma and Frank M. Goode

In a paper presented at the 1974 annual meetings of the American Agricultural Economics Association, Back argued that "the unsatisfactory state . . . of rural development policy reflects in part either an inadequate or inaccessible knowledge base" (p. 1125). Basically, he was arguing that research in rural development had not provided policy makers with the information necessary to formulate a cohesive national rural development policy. In addition, he argued that the institutional arrangements for conducting rural development research have helped create this knowledge gap.

Edwards suggests an alternative reason for the knowledge gap. He argues that the rural development researcher is faced with a host of partial theories of economic development but has no general theory to guide his empirical work. Although Edwards does not make the point explicitly, an implication is that the knowledge gap will remain until a comprehensive theory of rural development is forthcoming.

In this paper, a third reason for the continued existence of a knowledge gap is suggested. It is argued that rural development researchers have not done a good job of operationalizing and measuring the relevant concepts in the rural development process. The institutional arrangements for conducting rural development research can be improved, but additional conceptual work is needed. Significant progress can be made in bridging the knowledge gap given existing institutions and conceptual frameworks if more resources are devoted to operationalizing and measuring the relevant concepts. The objective of this paper is to present suggestions concerning how one might improve the operationalization and measurement of rural development research.

In his 1975 presidential address, Bonnen provided a useful framework for discussing these issues. He argued that a good information system must satisfy three conditions. First, it must have a good conceptual base. Second, special attention must be given to operationalizing the concepts; that is, the phenomena being measured in reality must be highly correlated with the concept. Third, the real world phenomena involved must be measured accurately. Each of these three conditions will be addressed below in the context of rural economic development.

Conceptualizing Rural Economic Development

In this section Bonnen's first criteria, namely, the conceptual basis for rural economic development, is discussed. In an attempt to narrow and focus, rural economic development is assumed to be reflected by increases in employment and/or income. The major determinants of income and employment in a given economic space (a rural community) are the quantity of the goods and services sold to and inputs purchased from outside the community and the extent to which dollars entering the local area are "recirculated" within the local economy. Conceptually, the economic development of an area involves explaining the economic forces affecting the geographical location of firms producing goods and services or sales outside the area and the complexity of the local economy in terms of retail trade and service activities.

Edwards has surveyed and classified the theoretical literature that addresses these two questions and concludes that the suggested determinants of economic development are (*a*)

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supply, (*b*) demand, (*c*) space, (*d*) institutions, and (*e*) technology.

The difficulty is that little if any of the literature explicitly addresses these five factors simultaneously; however, the common theme in this literature is that private firms locate where they can maximize profits. The concept of spatial profit maximization can be used to integrate the five types of variables used in location theory for explaining the action of individual firms.

Briefly, an example of this integration is as follows. In the context of rural communities, it is realistic to assume that firms are price takers in the output market. The firms will be primarily concerned with the transportation cost to its market (spatial factors) because the market price net of transportation cost determines the demand curve faced by the firm (demand factors). On the other hand, the firms may be large enough to influence the price of the inputs they purchase in the rural communities. Thus, the supply of locally purchased inputs is of prime importance to a prospective firm (supply factors). In addition, a prospective firm's profits can be sensitive to state or local laws (institutional factors) regulating permissible, productive processes (technological factors).

In addition to economic factors, issues such as informal contacts and community attitudes toward economic development may be important in the firm's location decision. Rural sociologists are trained to deal with these issues, and their input is needed if our analysis of the rural development activities is to be complete.

In essence, the underlying assumption of location theory, as detailed in the five types of factors suggested by Edwards, is spatial profit maximization. This, it seems, is a widely accepted theoretical framework that provides an adequate base for empirical work concerning the location of firms.

The second issue concerns the extent to which the income generated by the exporting firm is "recirculated" through the local economy. The essence of this issue is what types of service and trade activities are located in the community. Conceptually, the location of these types of activity is similar to export activities. The issues are treated separately here because of the traditional separation in empirical and theoretical works. If asked the question, What will be the secondary income and employment effects of a new plant?, the typical response would be: conduct an input-output or export base study. In many cases this may be appropriate; however, in rural communities a new plant may result in significant changes in the local economic structure and trade patterns. Since trade patterns and economic structure are assumed not to change in the typical input-output and export base approaches, these techniques are not directly applicable. Fortunately, Losch (and to some extent Christaller) has provided a solid conceptualization that explicitly addresses community economic structure and trade.

One can argue that there is an adequate theoretical model to explain the geographic location of economic activity. Though it is in need of improvement, this model does satisfy Bonnen's first criterion.

Operationalizing Key Concepts

The general theoretical model outlined above has been of limited usefulness to policy makers because the relationships in the model have been subjected to very limited empirical testing. One of the major reasons for this is that the concepts (or variables) in the model have not been carefully operationalized and measured (Bonnen's second and third criteria).

The general model suggests that the supply of labor at a potential plant site affects the profit function of a firm. Empirical information indicates that many of the firms that locate in rural areas are labor intensive. Thus, one can hypothesize that there should be a strong positive relationship, *ceteris paribus,* between available labor supply and the location of new firms. To test this relationship one must, among other things, operationalize and measure the concept of "labor supply." An example of how to operationalize and measure this part of the general theoretical model is discussed in the remainder of this paper.

How can the concept "supply of labor" be operationalized? The optimum would be to develop estimates of the "labor supply" function at alternative points in space. However, this is unwieldy if not impossible. An alternative is to employ an adaptation of the method used by firms to test the availability of labor at potential sites, namely, a "blind" advertisement soliciting job applications. As a rule of thumb a firm should obtain three to four applications for each position. In terms of the gen-

eral model, the firm's managers are attempting to establish that they are facing a highly elastic supply of labor. If firms make decisions based on this operationalization of the concept of labor supply, then it can also serve as a starting point for research.

In essence, the firm's blind advertisement is asking the question: If we create a specific number of jobs of a particular type at a point in space, how many additional people in the surrounding area will participate in the labor force and will commute to the new job? The three central issues involved are commuting behavior, labor force participation, and the type of jobs being created.

The first of these issues, commuting behavior, has received some attention in urban areas but little if any in rural areas. However, there is a substantial amount of literature in the general area of economic and social interaction over space. The most popular methodology in this area is the gravity model that holds that the interaction between two points in space is positively related to the mass at the two points and negatively related to the distance between the points. Applying this general model to rural commuting behavior results in a regression model:

$$(1) \quad V_{ij} = a + b_1 ELF_i + b_2 EMP_j - b_3 D_{ij},$$

where V_{ij} is volume of work trips from i to j, ELF_i is employed labor force at i, EMP_j is employment at j, and D_{ij} is distance between i and j. If such a model could be empirically implemented and the relationship were strong, we would have a method to predict commuter flows in rural areas.

The second issue (labor force participation) has received some attention in urban areas but very little in rural areas. Labor force participation is believed to be a function of the social and economic characteristics of the population. However, in the rural setting, labor force participation may depend on the geographic access to employment. A regression model of the following nature could be used to investigate labor force participation rates:

$$(2) \quad LFPR_i = c_0 + c_1 GAE_i + \sum_{k=2}^{m} c_k SEC_{ik},$$

where $LFPR_i$ is labor participation rate in area i, GAE is geographic access of people in i to employment opportunities, and SEC_{ik} is social and economic characteristic of people in i. Again, if such a model could be empirically implemented and the relationship were strong, we could predict labor force participation rates.

These two regression models could be used in pursuing the original question of how to operationalize the concept of labor availability. For example, if a firm locates in area j, the geographic access to employment for area i is increased by some amount ΔGAE_i. From equation (2) the predicted change in labor force participation will be $c_1(\Delta GAE_i)$. The change in employment in area i is the change in the labor force participation rate multiplied by the population in area i: $c_1(\Delta GAE_i)(Population_i) = \Delta ELF$. Substituting this estimate of ΔELF into equation (1) yields an estimate of the change in the number of people commuting from i to j, namely, $b_1 \Delta ELF_i$. If this procedure is repeated for all of the areas surrounding j and the results summed, we have an estimate of the change in the number of people commuting to area j as a result of the new firm.

The regression models, equations (1) and (2), can be improved by using more detailed employment categories. For example, labor participation rates depend on an interaction between the social and economic characteristics of the people and the geographic access to specific types of employment, not employment in general. Likewise, commuting behavior is conditioned by occupational characteristics interacting with specific types of employment. Once the specific types of employment are incorporated into the model, the three issues mentioned above, type of employment generated, labor force participation, and commuting behavior, are included in the procedure for estimating labor availability. We now consider methods of empirically implementing this procedure.

Measurement of the Labor Availability Concept

The operationalization of the concept of labor availability discussed above involves substantial data requirements. In general, data requirements are a major reason why rural development researchers have done a poor job of operationalizing concepts. They have been unwilling or unable to collect the data necessary to empirically implement good operationalizations of concepts. In this section examples of how some of the measurement problems can be overcome are provided.

The first issue involved in the opera-

tionalization of labor supply was commuting behavior. A study by Fink of the trip distribution process in two specific rural areas provides an important first step for analyzing the commuting question. His analysis provides insights into the factors underlying the trip-making behavior of individuals in rural areas. The empirical model designed to measure the volume of trips between an origin and a destination was based on (*a*) the employed labor force at the origin, (*b*) the level of employment at the destination, (*c*) the commuting distance, and (*d*) the presence of intervening or competing employment alternatives between the origin and the destination.

The study areas were two rural counties in Pennsylvania. The units of observation were the minor civil divisions (MCD's)—townships and boroughs—in these counties. Imaginary points of trip productions (population centroids) and trip attractions (employment centroids) were established for each MCD (figure 1). These centroids were derived in a manner analogous to that of determining center of mass. Trip volumes moving between MCD pairs were calculated from school census data obtained from school districts in each of the two counties. (See the Fink study for complete description of the data sources referred to in this paper.) A 30 × 30 work trip distribution matrix was compiled for one county and a 26 × 26 matrix was prepared for the other, so that there are 900 MCD origin-destination trip pairs in the first county and 676 trip pairs in the second. Data on the employed labor force were obtained from the U.S. Census of Population (Fink). Employment data were obtained from Dun and Bradstreet data files (Fink). The commuting distance used for each trip pair was the straight-line distance between the population and employment centroids.

The construction of the intervening opportunity (IO) and competing opportunity (CO) variables was as follows. If the employment centroid for a MCD fell within the intervening opportunity triangle (figure 1), that MCD was taken to be an intervening opportunity. The IO variable was defined as the employment at the destination divided by the sum of the employment at all intervening opportunities plus the employment at the destination. Thus, the IO variable takes on a value of one when there are no intervening opportunities and approaches zero as the number of intervening opportunities increase. The competing opportunity variable is constructed in a similar manner using the remaining area in the circle in figure 1.

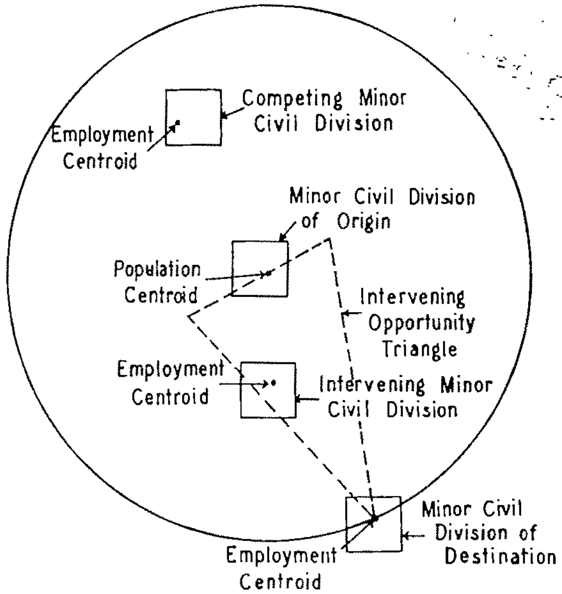

Figure 1. Spatial arrangement of population and employment centers

The basic approach followed in developing the trip distribution model was to estimate various models utilizing the data from the first study area. After a final trip distribution model was developed, it was tested with data from the second study area. The first model estimated was a crude three variable linear model that used commuting distance and aggregate measures for the activity systems of the origin and destination. The results in terms of the "signs" of the coefficients were consistent with those hypothesized. However, the low R^2 of the model indicated that a more complex model that takes account of the influence of alternative employment opportunities would be required to explain trip distribution. Thus, a new three variable model was developed in which the intervening and competing opportunity variables were entered into multiplicative interaction with the total available labor force at the origin and with the aggregate employment at the destination. Commuting distance was the third variable. The R^2 of this interaction model was 0.88. The results of this model when compared with those of the crude model suggest that trip distribution is conditioned by alternative employment opportunities.

Two additional sets of runs were made modifying the interaction model. In the first set of

runs, the IO and CO components were selectively removed from interaction with the aggregate employment at the destination. The resulting model appeared to be just as adequate for determining the distribution of work trips, i.e., R^2 remained essentially unchanged. Thus, the variation in trip volume explained by destination system interaction is negligible.

In the final set of runs, the IO and CO components were selectively removed from interaction with the total available labor force at the origin but retained with the destination. This reduced the R^2 from 0.88 to 0.26. The results of these runs indicated that the interaction between the origin activity system and the alternative employment opportunities was extremely important to determining work trip distribution. In fact, the results of all of the analysis indicate that the interaction of competing opportunities and intervening opportunity and the available labor force is the single most important factor determining the distribution of work trips.

From those runs a three variable model was selected as the final model. The variables include the available labor force at the origin in interaction with the IO and CO variables, the commuting distance, and the aggregate employment at the destination.

The final step of the analysis was to test this three variable model on a data set from the second study area. Substantial differences were found to exist in the distance and employment parameters of the models for the two areas. However, the interaction of the origin activity system and the IO and CO variables was even more pronounced in the second study area. Hence, it was concluded that the differences in the coefficients on the other variables for the two study areas were probably due to basic differences in the occupational structures in the origins or difference in the economic structure at the destination. Two additional studies—one on the characteristics of the labor force at the origin and a second on the economic structure at the destination—are now being undertaken.

A study designed to develop more specific and accurate measures of the labor force available at the origins is based on primary data from a mail questionnaire. The first objective of the study is to empirically estimate the relationships between various factors in a specific MCD and its labor force participation rate (LFPR). Further, the procedure is designed to permit comparisons of the LFPR for residents in various occupational categories. Implicit in this first objective is the determination of the relationship between the occupational structure and the trade-off between increases in income (wages) and commuting distance.

The second objective of this research is to integrate these results into the trip distribution model. Effectively, this will permit one to determine with a great deal more confidence the specific factors that affect the spatial supply of labor in these rural communities. One would hypothesize, for example, that the blue collar service worker would probably have a quite different set of factors explaining the economic space in which his services are available than would the college professor who "wants to get away from it all and probably even pretend he's a farmer." Again, the emphasis in this study is on the supply of labor as one component in the spatial profit-maximizing function.

The second follow-up study will emphasize certain aspects of the spatial demand for labor at the employment destination. The objective of this research will be determined by what occupational-employment combinations are most relevant in terms of labor force participation and commuting. The basic task will be to develop employment categories. The employment variable in the commuting and labor force participation models will be replaced with a set of variables reflecting employment levels in the various "disaggregated" categories. In addition, this study, using the tenants of central place theory, will help identify basic trade patterns that are hypothesized to be related to trip-making behavior.

These three studies represent our attempt to empirically implement the operationalization of the concept of labor availability. We are aware of several shortcomings of the procedure but believe the measure of labor availability to be superior to commonly used measures such as county unemployment rates. The latter are poor operationalizations and unemployment statistics in rural areas are poor measures.

Summary

The position taken in this paper is that rural development research should and can be compatible with the criteria outlined by Bonnen for good information systems—a satisfactory

conceptual base, operationalized concepts, and accurate measurement.

The location of economic activity, excluding location decisions by the public sector, is basically explained by a spatial profit-maximization model; that is, traditional micro theory, with particular emphasis on spatial input and output prices, provides a less than desirable but adequate conceptual base.

Labor inputs as a spatial supply factor—including the determination of the labor force participation rate—were discussed as an example of the implementation of Bonnen's operationalization-and-measurement criteria.

There is a knowledge gap that needs to be fulfilled in rural development research. But, one could argue that "matches and candles" are available so why curse the darkness.

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Analytical Institutional Economics and Rural Development Research: Opportunities for a New Synergism

Larry C. Morgan

During the past five years, the popularity of the rural development movement has waned considerably. The reasons for diminished rural development support among both public officials and researchers are numerous and complex, but the failure to adequately incorporate institutional change into research on community resource allocation must be regarded as one of the movement's major disappointments.

The economist's traditional inclination to study community decision-making processes, given a particular institutional setting, has resulted in a wide variety of powerful, market-oriented economic tools being applied in rural development research without much demonstrable evidence of success. Any researcher who has attended a public forum on rural development research results understands local citizens' frustrations with applied economic analyses where few, if any, parameters can be manipulated in support of community objectives.

A reorientation of perspectives is needed to bridge the gap between the market-oriented approach to rural development by most economists and the emphasis on the economic basis of collective action by analytical institutional economists. Both groups can make valuable contributions to rural development by synergizing their respective competencies in the development of a more precise theory of institutional change.

The Legacy of Oversimplification

Rural development research has suffered from the inertia of past approaches to rural development problems. Many of the initial perceptions of problems and analytical approaches to these problems were oversimplifications that have too often become a part of the rural development conventional wisdom.

The Problem of Rural Outmigration

Unfortunately, the publicity that influenced enactment of the Rural Development Act of 1972 portrayed outmigration and community decline as the major problems facing rural America. Countless public officials insisted that outmigration would have to be stopped or reversed if the quality of life in rural areas was to be improved. Not only has the wisdom of that assessment of problem priorities been questioned but it detracted attention away from the more fundamental and obstinate problem of conflicts among private and collective actions in small-area economies.

While rural development efforts were being organized to cope with rural decline, outmigration was apparently less severe than the popular impression. A new study of nonmetropolitan population patterns concludes that a majority of small towns and cities were not losing population during the 1950–70 period (Fugitt and Beale). Since 1970, metropolitan population has grown at a slower rate than nonmetropolitan population, leading to another popular, though oversimplified, impression of rural optimism and metropolitan pessimism.

The recent reversal of migration rates in many rural areas has been due almost entirely to factors other than rural development efforts. If increased rural industrialization and energy resource exploitation had not occurred, a "stop outmigration" policy would have further impoverished rural areas. Instead, a simulation study of seventeen popular rural development strategies indicates that a desirable strategy should be multifaceted, in-

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cluding a combination of job creation, labor force expansion, and improved resource productivity and capital utilization (Edwards and DePass). Such a strategy requires a major program to develop alternative institutional arrangements to assist where market processes have been unsuccessful.

The Importance of Self-Interest

The shortcomings of rural development efforts seem especially acute when compared with the contributions of economic research to commercial agriculture. But that comparison, however popular, is not an appropriate basis for evaluation.

Microeconomic theory holds a special reverence for the assumption that people will pursue their self-interest. In a market economy, self-interest is obviously a central feature of the resource allocation process. Beyond firm and household units, group action often supersedes the role of self-interest in community resource allocation processes. The allocation of public goods raises problems of free riders and technical externalities that are beyond the firm or household's control. Even the voting process often obscures individuals' community preferences and permits or invites the intervention of political institutions that may discourage the individual pursuit of self-interest to the detriment of community welfare.

Rural development research has been strongly influenced by the accomplishments in production economics. Studies dealing with the optimum size of cities, regional approximations of firm growth models, and the demand for public services are of limited value if market-oriented models are used with no provision for the influence of public goods effects. It is not much comfort to officials to learn that their town is either too small or too large in terms of per capita public service costs unless they have a method of comparing alternative schemes to achieve a size that meets the community's goals.

Institutional Change as an Economic Process

Criticism of the economist's failure to incorporate institutional change in the economic process is not entirely fair. The long-standing plea for a theory of institutional change remains essentially unanswered. I would expect sociologists to be leading the search for a concise theory, but recent writings by some of their leading scholars offer little encouragement (Blau). Among economists, the so-called "neo-institutionalists" are not much more advanced than the sociologists (Grunchy).

Davis and North have made a valuable contribution to institutional economics. The central role of self-interest in their theory of institutional change should help justify the study of institutional change as an economic process. Their theory is closely related to market activities and consequently may not attract much attention from noneconomists. The challenge of research in institutional change is to develop a theory that applies to both market and nonmarket activity.

Economic Rationality and the Institutional Setting

Hirschman's treatment of exit and voice offers a unique approach to the study of institutional change. Exit from a firm or organization is viewed as a traditional economic process. Failure to correct the cause of exit ultimately threatens the firm with extinction. Voice consists of efforts to modify the firm or organization without resorting to anything so drastic as exit. Voice might be classified as a noneconomic activity, but I regard it as activity to reduce uncertainty, extend or modify property rights, reduce or shift transaction costs and liabilities, and acquire rents, windfall gains, or other pecuniary or nonpecuniary benefits.

Voice falls within the scope of economic rationality since even random or nonmaximizing behavior conforms to basic economic theorems in response to changes in production and consumption opportunity sets (Becker 1962). Voice is thus a part of the institutionalizing process, an economic process where the "sets of ordered relationships among people which define their rights, exposure to the rights of others, privileges, and responsibilities" are modified to permit new production and consumption opportunities (Schmid, p. 893). This view of institutionalization rejects Georgescu-Roegen's argument that economics is not a theoretical science because the content of its fundamental principles is determined by the institutional setting (Georgescu-Roegen, p. 324).

The New Consumer Economics

The notion of "noneconomic" activity has been revised by the works of Becker (1965) and Lancaster on the economics of time. Any activity requires an allocation of time, which has an opportunity cost in some other use. Such a noneconomic institution as the family results from the allocation of time to maintain and enforce its working rules. The willingness of society to allocate time for such purposes ultimately reflects part of the social value of that institution.

The nonpecuniary nature of many activities does not justify classifying them as noneconomic. The task of measuring time costs (value) is formidable, but it promises to explain in economic terms why actions are taken to create, modify, or abandon institutions.

Information

Members of institutions or social movements frequently have to influence some other institution or individual in order to successfully establish working rules (Breton and Breton, Goldberg). The creation of influence involves not only time but the production and distribution of special types of information that is allocated according to its marginal value and marginal cost.

The cost of information is therefore an indirect measure of the value that members of an institution place upon either preserving it in its present state or modifying the working rules to enjoy new production or consumption opportunities. Lobbying efforts by the National Rifle Association against antifirearm laws are an ample demonstration of the great value its members place on the right to own firearms.

The Bureaucratic Perspective

Organizations form to gain the benefits of collective action. The bureaucracy, contrary to its popular image of inefficiency, is highly efficient at protecting itself from budget cuts (Downs, Niskanen). Government bureaucracies are particularly adept at lobbying to preserve their organizations' missions and their members' jobs. The bureaucrat's resistance to funding cuts is an economic action guided by self-interest, but it often results in political institutions being prolonged after they cease to serve a useful public purpose. The political institutions that have been created to support rural development are thus likely to drift into obsolescence as the bureaucracy's control and influence grow and emerge as impediments to further progress.

An Institutional Research Agenda for Rural Development

Among the many institutional problems that merit the attention of rural development researchers, those that pertain to political institutions created to support rural development are emphasized here. The premises that were cited to justify the creation of new laws need careful examination to determine whether they are still valid. The role of interest groups in lobbying for or against rural development legislation should be examined to estimate the value of their efforts to change the working rules. The bureaucracies administering the new laws should be scrutinized for evidence of atrophy and obsolescence of mission.

Area Planning and Development Districts

Multicounty planning districts have been created under the provisions of the Office of Management and Budget's Circular A-95. The districts were created to coordinate the flow of federal funds and render technical economic planning assistance to each member city and county. Serious doubts are now being raised about the organizational structure of the districts. Research is needed on the extent to which the district bureaucracies cooperate with other agencies to benefit their members. How effective are the members of their boards of directors in guiding the districts to accomplish community goals?

Health Service Areas

The National Health Planning and Resources Development Act of 1974 established multicounty health service planning areas, designed to form functional health service areas (HSA's), to coordinate the flow of federal funds to improve health services and to coordinate the construction of all new health care facilities that are intended to serve patients enrolled in federal health insurance programs. What methods were used to select the coun-

ties in each HSA? What interest groups attempt to influence the HSA's funding decisions and to what extent have they been successful?

The most fundamental research question on HSA's concerns their impact on the individual pursuit of self-interest to maintain adequate health care. How will voluntary associations and activities be affected by the HSA's decisions on whether new facilities can be constructed, even if a community raises the funds solely through voluntary contributions?

Title V Research

Title V of the Rural Development Act of 1972 provides for federal funding of rural development research. At least two aspects of the law should be studied from an institutional perspective. First, the law requires evaluation of each Title V research project to determine its effectiveness. Since evaluation is normally conducted by the project's researchers, there is ample opportunity to repeat one of the mistakes that has sparked intense criticism of the agricultural research establishment, i.e., producing trivial research results because trivial problems were proposed for investigation. The evaluation process should be studied to learn how rigorously and objectively it is conducted. The effect of evaluation on research performance should be analyzed to determine if new evaluation schemes are needed to stimulate more rigorous research and more challenging research problems.

Another feature of Title V that merits scrutiny is the role that state rural development boards play in setting research priorities and determining who does the research. Are projects approved in a manner that encourages low-risk research that has a correspondingly low value? Should competition for funding be opened to other research organizations outside the land grant, 1890 school group, such as the newly formed National Rural Center?

Concluding Comments

Most of the rural development research has had a strong empirical orientation. Until funding is available to provide incentives for more basic research on the economics of institutionalization, most of the applied research will have a limited payoff. The application of market models to community resource allocation problems often obscures the impact of collective action. More emphasis should be placed on developing a theory of institutional change that reconciles the market economist's perspective with that of the institutional economist. Unfortunately, far too many economists accept the rather obsequious notion that institutional change is an essence of the invisible hand's work and therefore inappropriate for further investigation.

Self-interest may not insure a Pareto-relevant solution, but it certainly should not be discouraged. The analytical institutional economist can make a valuable contribution to rural development research efforts by studying the extent to which political institutions that were designed to support rural development efforts are encouraging self-initiative and experimentation with new organizational arrangements. In this context, the accomplishments in environmental economics toward creating new institutions can make valuable contributions to other areas of rural development research.

Finally, the institutional arrangements that have supported rural development efforts need to be continuously evaluated for possible improvement. Agricultural economists have a rich tradition of offering alternative institutional arrangements in commercial agricultural policy. The challenges of institutional research will hopefully stimulate that same tradition in rural development research.

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Organizational and Institutional Aspects of Community: Some Conceptual Perspectives

Donald M. Sorensen and L. M. Hartman

> The hope that the pursuit of goodness and virtue can be postponed until we have attained universal prosperity and that by the single-minded pursuit of wealth, without bothering our heads about spiritual and moral questions, we could establish peace on earth, is an unrealistic, unscientific, and irrational hope. The exclusion of wisdom from economics, science, and technology was something which we could perhaps get away with for a little while, as long as we were relatively unsuccessful; but now that we have become very successful, the problem of spiritual and moral truth moves into the central position.
>
> E. F. Schumacher (p. 30)

There is a need for social science researchers and community development practitioners to focus on the fundamental problem of the loss of a sense of community in American life (sense of community is defined as the existence of shared meaning and trust among individuals). We see the problems of environmental quality, provision of public services, and concerns about other factors considered to be in the rubric of quality of life as symptomatic of this fundamental breakdown in community. The erosion of community is being accompanied by increasing attempts to maintain or strengthen organizational-institutional structures. We see these attempts as furthering the destruction of community. Rather than serving community-determined needs, professionals often unwittingly further community breakdown by serving institutional and organizational interests that impinge upon the freedom and dignity of human beings. This paper suggests that a more responsible involvement by the professional can help reverse the trend toward structural decay.

The first part of the paper develops a brief conceptual framework for an analysis of the community development situation. The second part elaborates the insights from this framework in an analytic, descriptive, and illustrative way. We conclude with some recommendations for university people derived from the analysis.

A Conceptual Statement

The conceptual framework is based on an empirically testable proposition: the basis for democratic social action is through shared meaning. Shared meanings are the essence of what is meant when one speaks of the cultural tradition. The continuing development of shared meanings is the dynamic of human evolution. Weber, in his classic *Theory of Social and Economic Organization,* develops a conceptual framework for the analysis of social organization premised on the concept of *verstehen,* or intersubjective understanding. The possibility of communicating presumes that the communicators start with some level of shared meaning; otherwise, communication is impossible. The only alternative to shared meanings for the existence of human order is force and behavioral conditioning. Historical evidence indicates that use of force to maintain order is a very unstable state.

Fromm in his book *Escape From Freedom* views modern societies as moving toward authoritarianism and force as sharing of meaning deteriorates among members of those societies. The concept of freedom is inextricably interrelated with the concept of shared meaning. Like freedom, meanings cannot be imposed upon an individual but must grow out of his own experience. Individuals must be free to make choices so that experience leads to the development of subjective meaning. The possibility of freedom implies trust among individuals who are significant and important to each other, and trust implies shared mean-

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ing. This leads us to the concept of community. The sense of community is defined by the existence of shared meanings and trust between individuals. As we have developed the argument, the sense of community is basic to the possibility of freedom and democratic action. Conversely, the sense of community is developed by freedom and democratic action and is synonymous with the concepts of trust and shared meanings.

Interpreting the current state of affairs in terms of the above propositions, one observes that the sense of community in rural America is being destroyed by centralized organizational structures. Economic, governmental, educational, and other centralized organizations are extending into the local community and are taking over the local functional action prerogative. This structural phenomenon evolves in a dominant framework of meaning focused on efficiency and utilitarian ends. This framework of meaning is internal to organizational structure (i.e., it meets organizational needs) and is not developed in a sharing relationship with the organizations' clientele. The evolution of centralized organizational structure is analyzed below in terms of concepts derived from our empirically testable proposition. According to Weber's conceptual scheme, a structural order develops out of common agreement upon desired ends and the apparent means to achieve the end; that is, effective structural order evolves out of human interaction in which people share meanings. This formal, structural, or vertical (we use the terms interchangeably) order is legitimized by the value agreement based in community. One must assume that our modern organization-institutional system evolved out of communities where some degree of agreement on ends and means existed. These formal structures have now taken over and are destroying community because the community has lost control over them. What was the historical nature of this process? Sufficient for the analysis here is the assertion that the agreed-upon ends of a technoeconomic nature resulted in an urban-industrial society where communication and sharing of meaning broke down. Bell's new book, *The Cultural Contradictions of Capitalism,* contains an excellent treatment of this phenomenon. In the twentieth century, rural America is losing community. As communication and sharing of meanings break down, means become ends within the formal structure. When the sense of meanings associated with the ends are lost, then mere expediency becomes the rule for action. In the process, efficiency, rationality, etc., become the ends for the organization, and communication is closed in to the organization itself. Serving the needs of its clientele or the community is of secondary importance. When one says the system has taken over, what is implied is that the internal order of the organization or institution provides its own justification, and for individuals to survive, they must conform to that order.

Conforming to an order, i.e., an imposed set of arbitrary rules and criteria for action, precludes the individual from developing shared meanings, which is one meaning of alienation. Alienation occurs when people are unable to share in determining what the rules are going to be. The individual must repress his own feelings simply to conform, and he is thus shut off from development of his own sense of value and meaning. Destructive and competitive self-interest or apathy and cynicism are the inevitable result, as Fromm and other humanistic-existential psychologists have so clearly reported. Developing community implies revitalizing the communication process within people who are alienated, i.e., those who are suffering from repressed feelings that result in apathetic or cynical attitudes and characterized by "dropping out" or by destructive and competitive behaviors. Communication processes involve both shared meanings and trust. The development of this process is not spontaneous, as the analysis above would indicate, but must be brought about by self-conscious leadership. Therefore, development of effective communication requires a "third party" where alienation has occurred.

Some Historical and Systematic Processes in the Loss of Community

Man's adaptation to his environment has been and is a process of community development. Throughout this process, man has created institutions and organizations in response to mutually shared human needs. The structural order in our early towns and villages was based on functional needs of the community as determined by local people and therefore had legitimacy and purpose. Essentially, control, ownership, and operation of these institutions were at the local level. There was a real sense

of community integration as functional needs provided the basis for structural development. This integration of functional (i.e., the face-to-face exploration and sharing of meaning) and structural (i.e., action according to agreed-upon or traditional meanings) dimensions gave people a sense of identity within the local community and, having found meaning in their life relationships, afforded legitimacy to local institutions. Implicit in the above is the belief that people in local community had a sense of shared destiny in addition to their identification with the larger society.

The consensually determined goal of economic development provided overall societal organization, but continued pursuit of that goal and the tremendous growth of organizations born of it has resulted in systematization and has brought about profound changes in the nature of the relationship between the structural order and the local community in America. Through time, a highly complex private economic and public support system has evolved in which concentration of capital, centralization of decision making, specialization of labor, and bureaucratization of organization are the predominant features. Carried to its logical conclusion, pursuit of economic efficiency means that increased control and predictability of events is essential. This means concentration of decision making and control of as many variables as possible, thus creating power to reduce uncertainty. Pursuit of these rational, calculating ends means that institutions and organizations have become self-enclosed social systems with internal criteria for measuring performance. No longer is primary attention given to determining the needs of people or to measuring the effectiveness in meeting these needs. Rather, pursuit of their own organizational self-interest means that primary attention is given to internal efficiency and control. Internal efficiency means the organization must be able to influence or even determine demand to minimize risk and uncertainty. Controlling both production and demand assures the maximization of profits.

The problems at the local community level become almost impossible to resolve as business, government, religious, and other institutions/organizations become systematized and operate solely from a narrow self-interest perspective. In pursuit of self-interest, competition rather than cooperative endeavor becomes the dominant reality. Problems are identified in self-interest terms, and conflict ensues as, for example, one group feels a new sewer system is needed and another feels a new library would be the best use of public resources. The problem is resolved through the exercise of power by the dominant interest group with little concern for the impact of their action on other interests. The community is torn apart, and no one experiences full satisfaction with the result.

If the various interest groups of the community could turn outward in an open sense of sharing with others in the discovery and exploration of feelings, then community priorities that people feel good about could be worked out because they become a cooperating part of, not competitive to, community action. This kind of interpersonal communication has largely broken down in local communities. As a result meaningful sharing of meanings stops, resulting in alienation, loss of freedom, and the capacity to act. Unfortunately, government bureaucracies with their "top down" designed programs and professionals with their narrow specialized disciplinary expertise further exacerbate the problem by serving special interest groups in or outside the community without first determining what it is the community really needs.

Conclusions

If the above assessment represents an accurate description of the contemporary scene, then we are confronted with a desperate need for renewing the communicating process so that shared meanings again provide the basis for determining human values. Somehow leadership must function so as to help people begin to share meanings and thus to establish their own control over their lives.

Many concerned social scientists, community development practitioners, and other professionals want earnestly to be more effective in helping to bring about human and community development in America. Unfortunately, the only model they know to attempt this is the one demonstrated to them through the highly structured and formal training programs that provided their professional credentials. They have been taught to believe that they can define people's problems for them, tell people the appropriate solutions, and thereby solve problems for people. Thus, the professional, based on the only meaning he has, develops programs that he thinks the community needs. He becomes perplexed when his expertise

fails to become assimilated by the community. The professional finds the institution/organization that he serves unable to respond to the leadership challenge. Certainly the church could be suggested as a source of this vitally needed leadership, yet organized modern religion has itself tended to become systematized with emphasis on religious form. Having abdicated its mission to help people find and share meanings for their lives, the modern church has lost its position of developmental leadership for modern man. So long as the universities, social scientists, and community development practitioners continue to maintain primarily an associational and disciplinary orientation, our involvement in community is likely to further the alienation process rather than foster integrating forces. Again, this is so because we force our cognitive framework for analysis and action upon community people.

As noted above, the social scientist or community development practitioner already has his own preconceived way of viewing the world from the perspective of his own discipline and has decided what he can do for people before arriving in the community. Values are not something he has been taught to be concerned with because they are determined externally from his discipline. Therefore, the expertise he brings is an abstracted body of specialized knowledge he knows the people need. It is considered unnecessary and, in fact, bothersome to try to relate to people in a sharing, uncertain relationship in which both community people and the professional work out their meanings and establish need priorities. When people are unresponsive or openly hostile to outside intervention by professionals, the social scientist or the community development practitioner naively attaches such terms as apathetic, rural radicalism, provincialism, or stupidity to these reactions. However, the professional's lack of sensitivity is a result of his formal training and the expectations placed upon him. Therefore, he has not discovered how to free himself from the formal or vertical perspective that leaves him trapped and unable to make his expertise available for assimilation by the community. By remaining unresponsive, people in community are attempting only to protect themselves from further alienating forces represented by the professional. The professional often is not sufficiently integrated himself to feel secure in letting the problems of the community determine his participation and insists on staying securely within his formal professional role. Moreover, he expects people to relate to him at his level of cognition, which itself is alienating and grossly inadequate to addressing the fundamental needs of the community.

The professional who develops the knowledge, skill, and commitment necessary to human development can choose to initiate functional leadership necessary for helping people share meanings in an open atmosphere where values and cognitions evolve through mutual effort. The professional can begin by helping people communicate effectively so that their meanings are heard and shared by other members of the community. Individuals have to relate effectively in order to share, they must share in order to develop and know their own feelings, their feelings must provide the basis for human values, and they must have a sense of values that provides a basis for action and a fully integrating and functioning personality.

We suggest beginning by facilitating the sharing of meanings, including our own, in a mutual effort to establish structures for serving human ends. This means establishing a new methodology that transcends the traditional quantitative, technical and nonevaluative content of our relationship with people in community as the primary focus. This does not mean that the current structural order is of no use; it means that a more horizontal approach in which community people and organizational representatives and academic persons are mutually open to each other can lead to a reification of human relationships and to an enhanced organizational-institutional responsiveness for fostering development of creative human potential.

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Private Property and the Development of American Agriculture, 1776–1976
(Wayne D. Rasmussen, Economic Research Service, USDA, Chairman)

The Role of Private Property in the History of American Agriculture, 1776–1976

Terry L. Anderson and Peter J. Hill

Two hundred years ago when Adam Smith described the way in which the invisible hand of the market place would organize society's output, he had no intention of implying that this invisible hand was to be unconstrained. On the contrary, Smith recognized that the rules under which buyers and sellers operated were crucial to the outcome. The structure of property rights has always played and will continue to play an important role in determining the way in which resources are organized for production, and the agricultural sector is no exception.

The history of agriculture contains many chapters on the methods of organization, ranging from communal to private, and the debate continues as to which system is "best." Recently, it has been argued that even the neolithic revolution that witnessed the switch from hunting and gathering to settled agriculture found its roots in the rules that governed production. In the words of North and Thomas,

> The solution to the common property dilemma in which prehistoric man found himself was the development of exclusive communal property rights. While animals and plants remained abundant relative to the demands of the human population, there was no incentive to incur the costs of establishing property rights over them. It is only during this transitional phase of increasing scarcity that it became worthwhile for man to incur the costs necessary to develop and enforce property rights that would limit the rate at which the resources were exploited (1975, p. 26).

Often the concept of private property rights is taken for granted in this country, but it should be recognized that the same evolutionary process to which North and Thomas attribute the "first economic revolution" is responsible for the current organizational structure (1975). Colonists landing on the shores of the New World found it necessary to adapt the rules they had known in their mother country. The founding fathers were faced with the problem of determining the proper federal land policy, while those who ventured into the western frontiers found it necessary to adjust those rules to their needs. When those frontiers closed, the farmers were faced with further adjustment to a more urban world. The rules governing economic organization have varied over time in the United States and will undoubtedly continue to do so.

Our purpose here is to explain the evolutionary process that has tempered the structure of property rights in the agricultural sector and discuss how these rules have affected resource allocation. To understand this process, we must first understand what is meant by property rights and what factors determine how these rights change. Within this context six periods in American agricultural history will be briefly examined: the adjustment to new conditions in colonial America, the formation of a national land policy, westward expansion, the closing of the frontier, the new role of government, and the recent environmental movement. An understanding of the factors influencing major changes in the institutional

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Discussants for this session were A. Allan Schmid of Michigan State University and Robert D. Reinsel of the Economic Research Service, U.S. Department of Agriculture.

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framework should provide insight into what lies ahead.

The Evolutionary Process

The rules that establish access to and use of both physical and human resources and the outputs therefrom are perhaps the most important determinants of the game's outcome. By assigning responsibility, private property rights force the self-interested individual to consider the costs and benefits of his decisions. In other words, the structure of property rights will determine how individuals or groups use resources, what goods they produce, and who bears the costs and reaps the benefits of actions. (For a more lengthy discussion of how rules evolved and how they influence activity, see Anderson and Hill, in press.) When exclusivity and transferability are insured through private property rights, resources move to their highest valued alternative subject to the constraint of positive transaction costs. Decision makers guided by the invisible hand and private property rights promote efficiency and raise society's output to its highest feasible level. When exclusivity and transferability are lacking, certain costs and benefits be externalized, and inefficient allocation will result.

From the above discussion it appears that efficiency is a simple matter of establishing private property rights, but this simplistic solution ignores the question of how such rules are established. The rules evolve through a process of interaction in which the rule makers assess the perceived benefits and costs of alternative rules and act accordingly. By determining the extent of access to and use of resources, the adopted rules influence society's as well as the individual's wealth position.

We have postulated elsewhere that "establishing and protecting property rights is very much a productive activity toward which resources can be devoted. But, like any other activity, the amount of this investment will depend upon the marginal benefits and costs to investors of allocating resources to these endeavors" (Anderson and Hill 1975, p. 165). Efforts to change the rules can be thought of as input into the production of an institutional structure. The demand for such input is determined by the value of the desired rule change as perceived by the decision maker and the likelihood that the proposed activities will achieve the desired change. The individual will be motivated by his perception of private benefits and costs, which may differ from those of society. In the case of establishing private rights, for example, the action may have "public good" aspects that result in an underinvestment in such activity from society's perspective. On the other hand, if desired rule changes merely transfer rights from one owner to another, net private benefits may exceed net social benefits, and too many resources will be devoted to these efforts. Nonetheless, an equilibrium will be established by the equalization of marginal benefits as described above and the marginal costs of activities, the latter being a function of the opportunity costs of resources involved.

To illustrate the use of this model, consider the example of recent efforts by various groups of Indians to reobtain title to their ancestral lands. Three factors fit into the explanation of this activity. First, the value of the lands has been rising over time and is likely to continue to do so. Second, a higher education level among the Indians has better equipped them to attempt the changes within the legal system. Finally, recent court decisions in favor of the Indian cause have significantly increased the probability of their success. These factors suggest an increase in the marginal benefits of rule change activity that should induce the observed efforts. These simple concepts are applied to the evolution of property rights in American agriculture.

Property Rights in Agriculture

In the course of American history there have been many changes in the structure of property rights as they pertain to the agricultural sector. At the same time, the inhabitants of this nation have been faced with many different combinations of factor endowments and different precedents within the legal system, which help explain the evolution of the existing property rights system and the impact the system has had upon output. The application of the above analysis to six periods in American history will shed light on the evolution of this system.

Adaptation in the Colonies

Since the early colonists came mostly from England, it is hardly surprising that the U.S.

property rights system bears a great deal of similarity to that of the mother country. After centuries of evolution, seventeenth-century English law was increasing its recognition of the private rights of citizens, especially with respect to land (North and Thomas 1974). Hence, "the institutions which the English settler brought with him provided a hospitable background for growth" (North, p. 48). Because actual conditions in the colonies differed from expectations, adaptation of the rules began almost immediately.

In both the Chesapeake Bay area and New England, initial settlements attempted some form of communal property system. The Virginia Charter, for example, required that all "fruits of their labours" as well as "all such other goods and commodities which shall be brought out of England" be put into one store and divided equally (Commager). But the results of such system spelled disaster for the colonists. "Its [common property's] strangeness, the fact that it was so contrary to the agricultural tradition they knew, was discomfiting. There were drones who idled while others labored, and in a land where every hand was needed to survive, there were women who would allege weakness and inability to avoid weeding and hoeing. There was a very human tendency to work less for the common good than one would work for one's own good" (Rutman, p. 6). To remedy the problem in Virginia, each man was given a small garden plot from which he was to provide his own food. This dispersement of land from the London Company marked the first form of private ownership in the colonies. In New England, where each family was granted an acre of land and the livestock were divided among the colonists at an early date, "the end of communal agriculture was a boon to the settlement" (Rutman, p. 12).

With time the system of private ownership in the colonies became better defined and enforced. Where good farm land was scarce, this evolution was more rapid. The New England geography, for example, combined with the commercial aspects of the economy meant that settlement was more likely to be concentrated. The potential for conflict over property rights raised the benefits from definition and enforcement, which in turn produced a system for surveying and recording land ownership. Farther south in the Chesapeake Bay region, however, this concern with the land system was much less intense. Land was more homogeneous and of good quality, transportation was available to most tide water land via rivers, and economies of scale were few, so the congestion and hence the potential for conflict were reduced. We should not be surprised, therefore, that well-defined and enforced property rights in land did not evolve as rapidly there.

When the colonies declared their independence of the mother country in 1776, colonial farmers had established the rights to alienate and inherit land, rights that were crucial to efficient agriculture. To be sure, there were some regulations of land use, and the government had retained the rights of eminent domain, police power, and taxation. Nonetheless, by the time of the Revolution the landowner had basically acquired the right to use his land as he saw fit with few restrictions and controls by the government.

The property rights structure that existed in 1776 was more than just the result of economic forces. The colonists inherited a strong philosophical ideology that adhered to the concept of natural law. Under this ideology individuals were vested with certain rights, and it was the states' function to codify and enforce these rights. Included in this package of vested rights was the right to private property, a right that the state could neither create nor destroy. The embodiment of these rights in the Constitution, with its emphasis on the importance and sanctity of the freedom of contract and the subsequent interpretations of that social contract by the Marshall Court, firmly established the principle of private property in the legal and economic system. Thus, from the very beginning of this nation a firm basis was laid for an efficient allocative mechanism in agriculture—a property system that provided strong incentives for increases in production.

Federal Land Policy

The nineteenth century was marked by the movement of agriculture across most of the continent, with large-scale increases in production coming from the settlement of new lands and from technological advance. In both of these, however, the ability of the farmer to capture all or most all of any output increases was crucial to the rising output that occurred. The property rights system internalized the benefits (and costs) of most decisions and thus led to efficient resource use. A major influence in determining what property rights

structure would prevail was the land policy of the federal government. Although by 1776 a set of institutions had developed that provided for private property in most of the settled land, formal property rights were not established over much of what is now the United States. The new nation was faced with some crucial decisions about the form those rights would take.

During the first half of the nineteenth century the government at both the state and national level moved rapidly towards a policy of establishing private rights in land. Such action was spurred on by a basic attitude that the energy of the unpopulated continent should be released, which could be best accomplished by the private actions of the citizenry. The impact of this land policy was felt most in the agricultural sector that dominated our early economy.

To be sure, the transfer of the public domain to private ownership entailed numerous costs, but those costs were lessened by two important developments early in the nation's history. In 1785 the Continental Congress passed the Rectangular Survey Act, which made establishment and enforcement of property rights much easier. Secondly, between 1781 and 1802 the various states ceded their claims to western lands to the federal government, again significantly lowering ajudication costs in establishing rights (Commager).

Initially, the federal government saw itself simply as a wholesaler of land, and disposed of large blocks of undeveloped territory to interested individuals and companies. Although the term "speculator" is often applied to these land purchasers in a pejorative sense, this policy did establish private rights very rapidly and quickly allowed the market to allocate land to its highest valued use. Because of a general disapprobation of "land speculator profits," the federal government gradually moved from being a wholesaler of land to being more of a retailer.

The growing concern for equity in land policy culminated in the Homestead Act of 1862, which, although it put severe restrictions on efficiency in land holdings particularly in the arid West, did embody community sentiment about appropriately sized land holdings. Although there were significant social costs to the Homestead Act and its various modifications, it did allow for the establishment of private property rights, albeit at a higher cost than previously. But perhaps of even greater significance was a general movement away from the establishment of individual rights to a policy of maintenance of group (governmental) rights in land. The twentieth century saw the government at both the state and federal levels move to more firmly establish its rights in the land that it held, in sharp contrast to the nineteenth century, which can be characterized as a period of rapid establishment of individual rights.

Westward Expansion

> The Easterner, with his background of forest and farm, could not always understand the man of the cattle kingdom. One went on foot, the other went on horseback; one carried his law in books, the other carried it strapped round his waist. One represented tradition, the other represented innovation; one responded to convention, the other responded to necessity and evolved his own conventions. Yet the man of the timber and the town made the law for the man of the plain; the plainsman, finding this law unsuited to his needs, broke it and was called lawless (Webb, p. 206).

By the time the first settlers were beginning to enter the American West, a system of defining and enforcing property rights in the productive agricultural inputs had evolved in the East. Surveys of the many small farms established the boundaries of each productive unit, positive identification by natural markings, combined with rail fences made from the available wood supplies provided for definition and enforcement of rights in livestock, and riparian rights determined access to and use of water in the streams. Just as the colonists of the New World imported a set of rules inherited from the mother country, the "colonists" of the American West borrowed from their eastern heritage. By the same analogy the western colonists were forced to adapt their rules to fit the resource endowments found in the new country.

Initial land endowments relative to the population in the West made the returns to the establishment of private property rights quite low. "There was room enough for all, and when a cattleman rode up some likely valley or across some well-grazed divide and found cattle thereon, he looked elsewhere for range" (Osgood, p. 182). Squatter sovereignty was sufficient for settling land ownership questions during the early periods of settlements, but increased population density changed the level

of property rights activity. Such activity ranged from the description of "accustomed range" in local newspaper advertisements to the filing of legal documents of ownership and the fencing of the open range with barbed wire in the 1870s. Between 1860 and 1900 changing land values and changing costs caused individuals and groups to devote more resources to definition and enforcement activity in order to capture potential rents to land. These efforts included not only control of land held privately but also control of grazing on the public domain. The result of these activities was a successive movement toward exclusive ownership of land on the Great Plains.

Property rights in cattle followed much the same evolutionary process. The most efficient size of operation on the Plains was vastly larger than that in the East, and the lack of fencing materials prior to the introduction of barbed wire made fencing out of the question. Hence, western ranchers were forced to turn to alternative methods of defining and enforcing property rights. In the absence of ownership conflicts, the return to establishing and enforcing property rights in cattle was low, but "the questions arising over the ownership of cattle and the rights of grazing, difficulties that have bothered the pastoral industry from the beginning of time, were intensified as the number and value of the herds increased" (Osgood, p. 114). With this came the increased use of branding and efforts to establish brand registration laws as a means of defining and enforcing private ownership rights over livestock. Again the western agriculturalist was forced to adapt the institutional framework to fit his needs.

Finally, in the case of water rights, the unique endowments of the Great Plains led the frontiersmen to invent and adopt an ownership system unique to their region. The initial adoption of the riparian system made sense for two reasons: the precedent in eastern law made the rules easy to implement in a legal system founded in the East, and the initial abundance of land adjacent to water made the riparian system adequate for the allocation of that resource. However, again as the settlement pressure increased, the returns to activities aimed at changing the rules of the game also increased. Spurred by such activity, a system of water law evolved that granted to the first appropriator an exclusive right to the water and to later appropriators rights conditioned upon the prior rights of those who have gone before, permitted the diversion of water from the stream so that it could be used on nonriparian lands, forced the appropriator of water to forfeit his right if the water was not used, and allowed for the transfer and exchange of water rights between individuals (Dewsnup and Jensen). That this system is strongest in the areas where water is not scarce, is combined with the riparian system in the states bordering the most arid portion of the Great Plains, and is not used to any significant extent in the more humid East suggests that benefits and costs do significantly influence the property rights system.

The Closing of the Frontier

Although much of the agricultural history of the United States can be described as a continuing process of defining and enforcing private rights in inputs, other concerns did come into play during the last half of the nineteenth century. Well-defined and enforced rights do minimize externalities and promote efficiency, but individuals will attempt to change the rules for reasons other than efficiency. The decision maker may use his resources in an effort to affect the transfer of existing property rights from another owner to himself. Such efforts were very much a part of farm organization activities during this period.

It was also recognized that the cost of establishing private rights in some areas was too costly and other solutions resulted. The granting of public lands to railroads can be viewed as a means of allowing those railroads to capture a greater portion of the social rate of return on their investment than otherwise would have been possible. Likewise, the passing of the Morrill Act in 1862 was occasioned by the belief that the advancement of agricultural knowledge was not being carried out rapidly enough by the private sector. Although it took several decades for agricultural research to bear much fruit, Griliches's estimates of the social rate of return on a single innovation, hybrid corn, indicates that there are significant externalities in such research.

During the last quarter of the nineteenth century the closing of the great American frontier changed the attitudes and opportunities of farmers. Cheap land, considered by some as a "safety valve" for many economic and social problems, was mostly spoken for by private individuals or by government agencies. Agriculture had expanded into the fron-

tier regions of the country where in many cases the soil was fertile and new technology readily adaptable. The results of this expansion were manifested in several ways. First, agricultural output increased at an unprecedented rate. Between 1869 and 1914, wheat output increased by 309%, corn by 322%, oats by 375%, cotton by 644%, and cattle by 250%. Total farm output increased "about 200% during this period, while the nation's population increased about 150%" (Higgs, p. 80). Second, as output was increasing, prices at the wholesale level were falling.

> The productivity improvements themselves, inasmuch as they meant expansions of output, meant lower farm prices and, in view of the price inelasticity of demand for farm products, would have meant lower total gross farm incomes if demand had not grown simultaneously. The competitive nature of the industry insured that improvement was rather readily passed on to consumers in the form of lower prices. . . . But, in fact, the demand for farm products, even with large accessions of export demand, did not grow as fast as total demand in the American economy (Davis et al., pp. 403–4).

Hence, absolute farm prices were declining as were absolute and relative incomes (Higgs, p. 100). Finally, the closing of the frontier and the continued growth of the demand for land meant that land values in many areas appreciated rapidly. While these increases most certainly augmented the income of land owners in the form of capital gains, they also appeared as higher input prices that were real opportunity costs to all. Coupled with the above problems was the market instability experienced by agriculture's entry into wider trade areas and the concern for concentration of economic power in the hands of a few.

During this period numerous agrarian protest movements entered the political arena in an effort to influence the perceived low and fluctuating farm incomes, the high nonfarm prices thought to be caused by monopoly power, and the wide margins between farm and market prices. "Farmers' faith in untrammeled individualism was modified by demands that 'something be done' by government or by voluntary association to stabilize farm incomes and to improve and maintain the relative standing of the family farmers in the economy" (Davis et al., p. 410). Groups such as the Grangers, the Farmers' Alliances, and Populists rose to the challenge of obtaining for the farmers their "fair share." While such efforts were nothing new to the American economy, the magnitude of these efforts marked a major turning point. As illustrated above, the agricultural sector played a major role in the evolution of private property rights in inputs such as land. The major concerns during the late nineteenth century, however, might be characterized as questions of property rights in outputs. The claims of "too low" agricultural prices, "too low" farm incomes, and "too high" freight rates can be interpreted as claims that farmers desired property rights in a larger share of the total market value of their output. The agrarian protest movements of this era can be viewed as efforts to muster resources to define and enforce these rights. However, acquiring these rights necessitated a transfer from other owners.

With the perceived concentration of power in some input markets such as railroad transportation and grain storage, the farmers saw increased benefits from group action that could be used to countervail these monopoly elements. The declining prices received at the farm also added impetus to the protest movements by giving the protestors more to gain if they were successful in their efforts. On the cost side of the ledger, falling farm incomes reduced the opportunity costs of resources devoted to changing the rules. Rather than spending extra hours in the field, it may have been much more productive to attend Grange meetings in the hope of increasing the return on crops produced. Moreover, during this era the effectiveness of group organization increased. The idea that power could only be resisted by power became commonplace in American attitudes as individuals joined their fellows to use the law to further their economic, social, or civic interests.

Nothing New—The Early Twentieth Century

During the last twenty-five years of the nineteenth century, farmers made great strides toward the organization of their efforts to increase farm income through collective action. This was not the first time members of the agricultural sector had engaged in such efforts; for example, farmers were involved in the formulation of the country's tariff policy during the early years of nationhood. But their primary focus up until the last quarter of the nineteenth century was with the definition and enforcement of property rights, especially in land. Even though by the end of the century

the organization effort was at a low ebb, there is little question that farmers had made their mark and that they would continue to do so. "They had demonstrated that organized farmers could exert a significant influence on national policies. Much had been learned about tactics in the attainment of given ends, and the dangers of direct political affilitation with specific parties" (Benedict, p. 114).

Because of this success of the agrarian movement, efforts to organize probably would be more productive, and more collective efforts might occur. In the context of the theory presented herein, with the groundwork laid, the marginal benefits from activity designed to define and enforce property rights in higher incomes should have increased. However, marginal costs reduced the amount of such activity during the first fifteen years of the new century. Good years for the farmer made his time in the field more valuable and increased the costs of devoting resources to collective action. Between 1900 and 1915 farm prices continued an upward march that left them more than 50% higher by the end of the period. Rising incomes that accompanied the rising prices earned the era the designation of "the golden age of agriculture." These good times reduced the relative net return from collective action and hence the amount of such activity.

The impetus for a revival of organized political activity came from the deterioration of the "golden age." By the middle of the second decade of the twentieth century, homesteading had slacked off and was no longer providing for agricultural expansion. The advent of World War I and the policies of the government during that conflict kept farm prices and incomes up until 1920. Expanding overseas demand accounted for part of this prosperity. But when wartime credits to allied countries were discontinued in 1919, this demand fell off, and economic conditions in the agricultural sector began to change. This, combined with the signing of the Armistice, caused a sharp decline in farm prices in 1920 and an even sharper one in 1921. With the decreasing demand and an inelastic supply, wheat prices fell by one-half and corn by one-third. "Thus, by the spring of 1921, American agriculture found itself in a more unfavorable position than it had experienced at any time in the memory of men then living, or possibly at any time since the nation's beginning" (Benedict, p. 172). The stage was set for another surge of activity that would attempt to secure higher farm incomes through the coercive power of government.

The major focus of the activity was not much different than that which had existed twenty-five years earlier. The farmer's share of national income was below what was considered to be "fair"; prices dictated by the markets were "too low" relative to farmer's expectations. In other words, in the eyes of the farmer, a portion of the true social value of his product was not accruing to the rightful owner; somewhere in the market system property rights had been tenuated, and the government was called upon to correct the situation by redefining and enforcing those property rights. The market had not necessarily broken down due to the existence of concentration of power or externalities, but farmers perceived that such a situation existed.

The success of the "new farm movement" was insured by the advent of the Great Depression. To the U.S. farmers of the third and fourth decades of the current century, the costs of devoting resources to the establishment of "new property rights" were low since the markets for their products were yielding poor returns. In addition to these cost considerations was the fact that the progressive era had shown the potential effectiveness of organizing to influence the rules of the game. The potential for higher incomes, coupled with the expectation that they could be obtained if the organization was strong, raised the benefits from institutional change activity. Resources employed by the various groups were aimed at increasing the incomes of members by giving them the right to control output in their sector, to receive parity prices, and to have a say in the establishment of prices charged by input suppliers such as the railroads and grain elevators.

The success of their efforts is evident in the farm policy of the federal government that has emerged during this century. Bills such as the cooperative marketing bill of 1922, which exempted co-ops from antitrust legislation, the McNary-Haugen bills, which would have enabled government purchases of surplus commodities in 1924, and the New Deal price-support programs are all examples of the success of organizations such as the Farm Bureau. "By the end of the 1930's the agricultural price-support program, the basic program desired by the farmer, had become institutionalized into the American political structure, and has continued so in one form or

another since that time (Davis and North, p. 100).

The Environmental Movement

While a majority of the property rights activity of farmers in this century have been of the type described above, recent years have seen a return to the concern for property rights in inputs such as land and water. The conservation movement that began late in the nineteenth century was revived during the Great Depression, revived again during the past two decades, and might be seen as an effort by various groups to define and enforce property rights in resources that have no such governing rules. In the case of air, for example, the increasing scarcity of clear air has induced many to secure behavioral rules governing the use of that scarce resource. Land and water use have come under similar scrutiny, and since these resources are valuable inputs to the farmer, he has been forced to engage in the battle for rights.

Land use planning, described by some as the "taking issue," is an excellent example of the current issue. As land in general and open space in particular has become more scarce, the rate of return on defining and enforcing property rights in such resources has increased. The response of individuals to this return has resulted in a proliferation of rules and regulations governing land use, many of which transfer rights the farmer considered to be exclusively his to other groups or individuals without compensation to the farmer. The ability of the farmer to alter the course of a stream provides an example. While this is not a right guaranteed by law in most cases, it is one that the farmer thought he owned. Legislation designed to regulate stream use has altered these thoughts.

Efforts to alter the rights to resource use have raised the benefits to farmers from better defining the rights that they considered secure. In many cases existing organizations have turned their efforts to this cause, while in others entirely new organizations have been formed.

Summary

From colonial times through the first three-quarters of the nineteenth century the main focus of agrarian property rights activity was on defining and enforcing property rights in inputs, and his focus was instrumental in directing the course of private property rights, especially in land. From the last quarter of the nineteenth century until the present, the primary concern of the farmer has been with the establishment of private property rights in a larger share of the national income, and again these efforts were influential in setting the direction of federal policy. Now with the rise of water and land use planning, the agricultural sector is again concerning itself with the definition and enforcement of rights in inputs.

Farmers are not the only productive group in society that affect the type and distribution of property rights, but it is clear that they have had a voice. Their commitment to private property manifested itself in the large-scale output increases that the nation has experienced. On the other hand, their more recent concerns for equity have helped force open the door for increased transfer activity accompanied by government regulation. Clearly, the rules of property rights significantly influence productivity, and these rules are endogenous to the system. Hence, in this bicentennial year it is important that we consider the extent to which the present system of property rights encourages efficiency and promotes transfers not only in the agricultural sector but in the economy as a whole.

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Property and the Future of Agriculture

Gene Wunderlich

> Each recognition of a new thing as the object of legal rights has opened a new chapter in the law, often one of vast complexity. Philbrick (p. 692)

This paper is about complexity. I am going to examine complexity and property in two ways, a short way and a long way. The short way is a cowboy story, and the long way is the same principle explained in the words of an economist.

Consider the cowboy (this is an agricultural paper; apologies to the marine economists who are familiar with shipwrecked Crusoes). He rode alone into an open range with only his horse and saddle as property. He rounded up wild cattle of appropriate gender and confined them and their offspring until he had a herd. The herd grew by itself limited only by natural predation, cowboy consumption, and sales of beef to the folks back East.

Enter cowboy B who did likewise. Organizational opportunities consisted of a shoot-out (winner, if any, takes all) or a slightly more complicated property arrangement by which cattle were claimed and recorded by branding (if the cattle had any say, they would have preferred title registration in deference to their smoldering flanks). The cattle were comingled with cattle of other brands on the common prairie.

One year rain was short, as was the grass, and land for grazing became scarce. Organizational opportunities arose again. The options were another shoot-out or a slightly more complicated property arrangement by which the cowboys, then numbering three, agreed to limit the size of their herds by formula. The formula worked fine until the enterprising cowboys weighed the risks of cheating against getting caught. Organizational opportunities arose again, with the consequences of one or more shoot-outs or a still more complicated arrangement that conceded enforcement to a fourth party (they did not like the enforcer very much, so they called him government).

When the range became too crowded with cowboys, some of them took to growing clover for the cows and carrots for horses. But open range is a poor place to grow clover and carrots with cattle and horses around, so still more organization opportunities arose, leading to more shoot-outs or some rather complicated property arrangements involving surveys, fences, deeds, recording, *inter vivos* transfers, and *cavaet emptor*. Some of the cowboys could not speak Latin, so lawyers were invented. Cowboys no longer spoke or shot it out with other cowboys. Cowboys spoke to lawyers who spoke to other lawyers who spoke to cowboys.

Meanwhile, ranchland became scarce. The old free range became expensive, and cowboys discovered it was more profitable (and much easier) to sell land than to raise and sell cattle. Organizational opportunities abounded, but instead of shoot-outs there were contracts, litigation, and legislation. Leasing contracts, for example, allowed buying for just a short time. Land became so valuable that people could only buy or rent the separate services of land one at a time. Each of these separate services became a right. Computers were enlisted to maintain a continuous record of all the property rights. In time the land itself was forgotten, and major industry was built on the trade of real property rights. Organizational opportunities flourished even when the land did not. The story fades out in the year 2027 when a third generation cowboy and a battery of lawyers invented a transferable viewing right for the sunset over Rattlesnake Butte. [end of parable]

> The problem of the ownership of property is in my view, one of great importance and of common concern throughout the free world. Meade (p. 177)

We have been asked to consider, as part of the AAEA proceedings, the future of property and agriculture. The reason is plain. The rules comprising the institution of property affect

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the way wealth and income are distributed and resources are used. It is as important for us to understand future property rules as it is to understand future demands and supplies of petroleum, fertilizer, labor, or seed.

The task of translating the past into the future should not be difficult; it is a process used from early childhood. Each of us have learned, with varying successes, to identify important events and activities. So it is with the future of property. The future of property should be no more difficult to predict than the future of technology, society, and mankind. Nor is it, I fear, any less difficult.

The Approach

This is not the place for a discourse on methodology, but it is perhaps useful to distinguish between predictive models and reasoned speculation. The approach to the future of property used here is best described as speculation. It is doubtful if any treatment of the future can be much more. A model for prediction implies facts for testing that, by the very nature of the future, are not available. In Lachman's words, "the impossibility of prediction in economics follows from the facts that economic change is linked to change in knowledge, and future knowledge cannot be gained before its time" (p. 71).[1] Our speculation is about those human interdependencies and organizations of the future that pertain to property, especially land in agriculture.

Property Semantics

What is property? Ely remarked that "the essence of property is in the relations among men arising out of their relations to things" (p. 96). Others variously define property as a system of authoritatively sanctioned rights, duties, privileges, and liabilities among persons with respect to property objects (Wunderlich).[2] The objects might be goods, services, territory, ideas, or enterprises. The persons can be natural persons or legal entities such as corporations or trusts. The sanctioning authority is government or its substitute. The rights and duties are relations between the holder and others.[3]

The critical element to be distilled from the definitions and descriptions is "distribution." Property distributes opportunities and obligations among persons. Only indirectly, by personifying benefits and costs, does property prescribe use of things. The effect of property on decisions about the levels and combinations of resources is inferred from incentives presumed to exist from the distributive qualities of property.

The rights and privileges attending property are assumed to create incentives, which are assumed to create behavior with respect to resource use. These assumptions are so plausible that they seem not to have been seriously questioned, and the linkage between distribution of rights among persons, benefits and costs, incentives, decisions, and behavior have been fused into a doctrine of appropriability and liability. This doctrine provided conceptual underpinnings for the literature of externalities that bloomed in the environmentalist era.

Thus, some rather elementary ideas about property added immensely to economic understanding (Demsetz, McKean, Furubotn and Pejovich).[4] Unfortunately there has been little *quid pro quo*. Economics has not been equally generous to the concept of property. The "bundle of rights" remains more or less as stated by Noyes in 1936:

> this rather will-o'-wisp thing called dominion or ownership . . . is said to represent a bundle of rights of a certain nature with reference to a certain object. Other kinds of bundles may exist with reference to the same object. . . . All the aggregates combined, which have reference to a single object, constitute complete property in that object (pp. 309–10).

Describing property as a distributive instrument does not diminish its role in resource use. It merely affirms property as primarily an

[1] Shackle states further, "The analyst can reason only about what is in effect complete; and in a world where there is time, nothing is ever complete" (p. 27).

[2] The concept of property here draws from Ely, Hohfeld, the American Law Institute, Noyes, and from suggestions and ideas from Quintin Johnstone, Myres McDougal and Harold Lasswell; it is described in greater detail in Wunderlich.

[3] Hohfeld claimed that "one of the greatest hindrances to the clear understanding . . . arises from the express or tacit assumption that all legal relations may be reduced to 'rights' and 'duties' . . . ." (p. 35). He thereupon classified all legal relations into jural opposites (right, no right; privilege, duty; power, disability, and immunity liability) and jural correlatives (right, duty; privilege, no right; power, liability; immunity disability). Hohfeld's scheme was useful largely because it showed the implications of rights—privileges held by one party on the duties and on rights of others.

[4] Following Coase's concepts of social cost, Demsetz and others (e.g., McKean) explained externalities in terms of failures to assign property. The doctrine of appropriability, referred to as the "property approach" to economic efficiency issues, was reviewed in Furubotn and Pejovich.

aspect of the distribution of wealth, power, and status, which may in turn affect the way property objects (resources) are used. Looking at the future of property, one should give first priority to distribution of property rights and then examine the implications for resource use in, say, agriculture.

Complex Systems and Property as Information

Property is a system through which owners communicate to others their interests in property objects. Essentially, property is an information system. As the number of property objects, interests, and owners increases, the system becomes more complex. Simple one-to-one contracts give way to generalized rules. Then the general rules become numerous, requiring codifications with increasingly formal and elaborate procedures for enforcement, adjudication, and modification.

An expansion of property objects and persons would cause one to expect the property system to rely more on groups, voluntary organizations, and government to become the decision makers. These organizations have increasing needs for information. Systems capable of handling large volumes of information tend to become specialized. Davis and North explain the tendency:

> In general, not only is information costly, but it is subject to increasing returns. That is, one must frequently pay for information, but the cost does not change much whether that information is used to effect one, one hundred, or one thousand transactions. If information costs are substantial and if they are subject to decreasing costs, it is likely that substantial profits are to be earned from increasing information flows that decrease uncertainty (p. 21).

The market for land has traditionally been local and specific to a particular unit; each transaction has been, to a large extent, tailor-made. However, conditions surrounding the exchange of land are changing. Already a specification market is developing in urban residential real estate. Thus, according to Davis and North criteria, the conditions for institutional innovation exist in real property rights.

The increasing complexity of the real property system is an inevitable consequence of more parcels of land, more separable rights, and more rights holders. There are currently between 85 and 100 million parcels of land counted for tax purposes (U.S. Dep. Commerce 1974, Behrens). From these units of ownership, at least a third have separated a lease-hold interest (U.S. Dep. Commerce 1975). Most parcels are subject to some separations of interest such as easement, reservation, and covenant, or security, regulation, and tax.

What does this complexity mean in terms of the distribution of land ownership? It means that the bundle of rights is divided in many parts, and the parts are held by many people. What is called complexity in the property system may result in a wider distribution of real property than is indicated by available measures such as a Gini ratio of land ownership (Johnson). A small portion of a population holding fee ownership, for example, does not necessarily mean that the distribution of all interests in land is concentrated. The degree of concentration of land ownership may be an illusion resulting from narrowness of concept of ownership and the inadequacy of information about ownership.

The many interests in a parcel of land are much more difficult to identify and comprehend than the parcel itself. One tends to be object- (say, parcel of land) rather than concept-oriented, and the tendency is to assign to an owner a single interest to an object. This is revealed in the choice of the word "attenuation" in the property rights literature, for example: "By considering how the attenuation of basic property rights affects the actions of decision makers, it becomes possible to secure new insight in the behavior of various types of firms" (Furubotn and Pejovich, p. 1148). Attenuation connotes a diminution or disappearance rather than separation or relocation. Is it correct to say that a lease—the right to use a parcel of land for a given period of time—is an attenuation, or is it a separation of a use right from the fee ownership? Likewise, does an easement or regulation reduce or attenuate a right to use; or does an easement simply relocate a particular right, and a regulation represent the exercise of a right a government had all along?

The idea of attenuation results in part because the inadequate information quality of the present property system allows all the separable property interests, except the original fee, to disappear into oblivion. Presumably a more sophisticated information system could identify, record, publicize, trade, and tax each

of the separable property interests.[5] To do so would result in a more accurate valuation and marketing of separable rights. One of the interesting consequences of the recent attraction of transferable development rights is that separable rights for particular uses are distinguished and traded.

In the long run, the benefits to someone of developing the more sophisticated property information system will probably exceed the cost. The precondition for organization innovation, in terms of the Davis and North criteria, will exist, and enterprising individuals, groups, and governments will refine the market for property rights.[6] Interests in property will become more widely distributed, not merely attenuated.

The anomaly of power will be that, as the distribution of property interests become more widespread and as information systems become more specialized (high initial costs, low unit costs), new forms of concentration of property may arise. Particular types of interests may become the focus of information specialists who control access to information sources. To some extent the present limits on access to multiple listing in real estate is a step in that direction. As the information system becomes organized and regulated, access to the system may be restricted and its value expressed as franchise—a seat on the New York Stock Exchange, for example.

The concentration of economic or political power associated with the ownership of large amounts of land could be submerged by control of information about land. What the stock market has done for capital, the land information market will do for land.

The Future of Property

In general, what can be said about the future of the real property system in the United States? The following speculations and their consequences are offered as a step toward a better understanding of that future. The speculations are presented more or less in descending order of certainty and directed toward land.

(*a*) There will be more holders of property. Demographers project more people, and there is no reason for assuming that organizations, trusts, and other potential holders of rights will not increase with the number of people. There will be more property objects. Unless the human tendency to make and collect things change, there will be more ideas, goods, services, and continued vertical and horizontal divisions of territory. There will be more separation of interests (rights) in property. Wants will become more specialized and less enduring, so the rights, duties, privileges, and obligations will become more narrowly defined and will turnover more rapidly. Thus, the quantity of property interests will increase. The rules pertaining to the property interests will increase in number or include larger numbers of interests within each rule.

More legislative, administrative, and judicial resources will be required for the organizational overhead to manage larger systems. Success of future property systems will depend on highly sophisticated mechanisms for separating, identifying, transferring, collecting, and managing property interests. Information handling will determine the character of the institutional future.

(*b*) Property rights in land will become increasingly separated, permitting the retention of the fee in fewer hands, especially by groups and organizations. More of the interests in land held by individuals will be second-order interests, such as negotiable stock in a land-holding corporation. Land for investment will be held by incorporated and syndicated holders with security interests in large financial organizations. Property interests will be concentrated along classes of property, e.g., a single group may own all the development rights in an area. A power company may specialize in owning rights of way for the operation of an electric power grid. Some of the concentration will include government; for example, county government may hold scenic easements on all agricultural land to insure an overall visual quality in the county.

(*c*) New systems of classification, brokerage, marketing, and finance will permit more rapid purchase and sale of fee interests, leases, options, easements, and other separated interests. The real estate market will be increasingly national and international.

(*d*) Title assurance, recording, and registra-

[5] Conceivably each separate interest could be assigned a value and taxed. Such a system would be intricate but would have the advantage of precluding some current tax aberrations such as preferential use value assessment.

[6] Davis and North's model for institutional innovation, reduced from its refinements, is simply that an innovation will come into being when "there are potential profits that can be harvested by anyone (or any group) who can innovate new institutional arrangements that will overcome . . . barriers [of economy of scale, externality, risk aversion, political pressure, etc.]" (p. 61).

tion will be automated and simplified. Uniform standards will reduce costs and ease interstate and international transactions.

(*e*) Government will acquire, hold, and manage more interests in real property. Common property will become more common. The share of interests in land held by government will increase proportionally with the number of people, parcels, and interest separation. This speculation is based on the theory that as an organization, such as a nation, becomes larger and more complex, a larger share of total resources is devoted to management and coordination. At least some of the centralizing tendency will take the form of government.

(*f*) Against the centralizing tendencies of management in large-scale organization and the waste of coordination is the decentralizing tendency to form small-scale autonomous decision units. Polycentrism is the term given to systems whose elements make mutual adjustments within a general set of rules (Ostrom). Polycentric organization may permit refinement in property information without elaborate machinery for policing and adjudicating rights.

The Future of Agriculture and Property

> The condition most favorable to the prosperity of agriculture exists when there are no entails, no unalienable endowments, no common lands, no right of redempton, no titles. Polanyi (p. 180).

The future of agriculture will be determined by a large number of factors, including but not limited to property. Biological sciences will be the most important influence on the future direction of what is now called agriculture, but the property system will affect the distribution of benefits and costs and may have some effect on the direction and pace of change (Boxley).

The biotechnical features of world food and fiber in relation to population has been stated in the optimistic terms of Kahn and Brown:

> For the balance of this century, the prognosis is quite favorable for two-thirds of humanity . . . but quite ambiguous for the poorest third of the world. . . . Our assertion, however, is that these can be greatly mitigated and possibly solved by creating sensible programs within and outside the trouble areas. . . . Would there be enough food, we may still ask, if, after 200 years, the world population reached, say, 20 billion, about five times the current population? The answer to that question, we assert, is a simple yes!" (p. 332).

Paarlberg is less sanguine than Kahn and Brown (see Paarlberg 1976, Rasmussen):

> Agricultural production, even in the less developed countries, will probably increase at a rate somewhat greater than population over the next 10 years, so that per capital supplies of food are likely to increase moderately. The improvement will not be great, however, and it will not be sufficient to satisfy either the nutritional needs or the expectations of the people. . . . Let us now direct our attention to the long-term food problem, which will extend well into the 21st century. Unless there is a check in the rate of population growth, I see no solution to the food problem" (1975, pp. 300–301).

For those even less optimistic than Paarlberg, the biological image presented by Borgstrom is even more formidable:

> "Demographers expect the world population to double between 1975 and 2000. That means that even if we somehow manage to double world production of food, minerals, housing and everything else, more people than ever would still be starving and malnourished. The hunger gap can be removed only by trebling food production during the next 25 years.
>
> In biological terms, the true feeding burden of the planet is not 4 billion people, but rather 20 billion population equivalents (PEs): We must include livestock as well. A PE is a unit of protein intake; that of a human is one. The feeding population of the United States is 1.7 billion PEs, a number that includes 215 million human beings, 150 million pets, and livestock. The one billion more people the demographers expect in the next 13 years are really—in biological terms—five billion" (pp. 71–72).

In the long run there is little basis for optimism unless mankind can bring itself under biological control. In the short run, food and fiber production can be greatly expanded by mere extension of present knowledge. Control of insects and diseases, improved fertility and water management, soil conservation, and refined materials processing all will increase the capacity of the nation to produce food and fiber (Quance, National Academy of Sciences 1975a).[7]

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[7] For a more systematic examination of current food systems and near futures, see U.S. Department of Agriculture and some 1985 projections in Quance. The National Academy of Sciences report (1975b) is consistent with Paarlberg. The report is summarized with "For the next decade or so, we think we perceive that the supply of food, feed and fiber will be adequate . . ." (p. 102). But the report adds, "This period of adequacy, which we believe we can foresee, is somewhat irrelevant in view of the concerns raised in this report" (p. 102).

In the longer run at least two technological advancements—energy management (Steinhart) and genetic engineering—will greatly enhance the potential for food and fiber production and will also affect the organization of agriculture.[8] Solar energy is presently used at a small fraction of what might be available. There is great potential in methods to tap the power of the sun (Calvin). Plants may be used to store energy for fuel, particularly in humid areas. In arid areas solar power generation is possible through heat and steam or chemical generation of electricity. Solar energy, however, awaits major scientific and technological development before it becomes the main source of power.

The remarkable advancements in the science of genetic information clearly portends major development in food and fiber production. Plants and animals will be designed with a combination of selective breeding and DNA modification. Insects can be bred for toxic vulnerability to cheap nonpolluting poisons. Nitrogen-fixing qualities can be built into plants. Animals can be designed for market preferences. Many opportunities exist, but genetic engineering is in its infancy, and the scientific community is proceeding conservatively. The redesign of humans to expand economic capability of resources—smaller people, for example—is an intriguing possibility but unlikely in the near future.

With more energy and more efficient plants and animals to use the energy, the likelihood of the omnivorous, flexible homo sapiens to survive and prosper is great if not assured. The quality of life, satisfaction of demands, and specific adjustments of the supplies of goods and services will depend on population levels, structure, and tastes such as nutritional values.

The effectiveness with which scientific effort is encouraged and used will depend to a great extent on organization. It is almost certain that the agriculture of the future will look no more like today's agriculture than today's agriculture resembles neolithic food gathering. The organizational change from today's agriculture probably will be toward two general forms: the food and fiber factories, concentrated physically and financially to serve national and global transportation facilities, and the natural farms based on occupational (today's subsistence, part-time, and retirement farms), recreational (today's hobby farms but in greater number), and cultural (tomorrow's art form) objectives. The two organizational forms will coexist and to some extent support one another. Financial requirements will tend to centralize and concentrate the food factories. The hobby, art, recreational, subsistence, and other natural farms are to a large extent consumption activities. They will not influence the bulk of the food and fiber production.

Speculation about the likelihood of future of farm factories does not mean that they are particularly desirable or inevitable (Clark, Schumacher). The potential for monopolization of food availability and the potential for a calamitous interruption of supply are two strong arguments against food factories or other forms of concentration. With a direction of research and development of more intensive, safe, imaginative, and pleasant use of labor; small-scale technology; production techniques for small-scale enterprises; small-scale marketing and financial institutions, a widely dispersed production-oriented agriculture could persist for a long time.

If there is continued unionization of the labor force, concentration of financial resources, and emphasis on mass production techniques in agriculture, then the food factory is likely. Resource markets will correspond to the concentrated production organization.

Two markets for land will appear: industrial, where high prices for land will encourage capital intensity, which in turn will increase the price of land, and consumptive or subsistence. Capital-intensive, financially sophisticated food and fiber factories will tend toward a separation of property interests in land and a development toward second-order interests in land (negotiable, transferable interest in a land-holding entity such as a corporation or syndicate). The consumption or subsistence farms will involve less separation of interests in land than the food factories but greater parcellation; an appropriate analogy might be today's single-family detached home, compared to an apartment condominium.

Much of the future of property and agriculture would appear to depend on effective information management. Both biological and organizational processes, almost by necessity,

[8] The use of machinery in the United States has resulted in a net loss of energy, i.e., agricultural consumes through oil more energy in British thermal units than it produces in food. Moreover, the energy "subsidy" (calories of input in relation to calories of output) has risen from one in 1910 to eight in 1970 (Clark, p. 44).

will become more complex. In research, management, and legislation, information requirements will increase. Issues of privacy, independence, freedom, responsibility, interdependency, control, and equity will surface in many ways in many places. Better information, obtained faster and less expensively, will be needed to resolve these issues. The property system will be no exception.

The problem of organizational complexity and information as it pertains to property and agriculture in the past and in the future suggests two areas of social science research: historical theory of complexity, equilibrium, and growth of institutions and a theory of the conservation of information on which research and design of organizations could be based.[9]

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[9] By conservation of information is meant nothing more than the efficient use of information overtime—no more channels, no more messages, and no more encoders and decoders than necessary to reduce uncertainty to a desired level.

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The Demographic Shift Toward Rural Areas
(Lynn Daft, Congressional Budget Office, Chairman)

A Further Look at Nonmetropolitan Population Growth Since 1970

Calvin L. Beale

The fact that the trend of population growth in the United States had turned toward rural and small town areas began to become public knowledge late in 1973. It took a while for the information to be widely distributed and to be accepted, for it went against the grain of much that economists and others in research or policy positions believed probable. By now it has been widely reported in the news media and seems to be part of the public's general stock of information. The purpose of this presentation is to give an updated assessment of the trend and of the circumstances that are associated with it. (For an earlier and fuller discussion of the subject, see Beale 1975.)

The simplest way to show the trend is to compare growth and migration rates for metropolitan and nonmetropolitan areas. From April 1970 to July 1974, the nonmetropolitan counties of the United States increased in population by 5.6%, while metropolitan counties grew by 3.4% (table 1). Neither of these rates is especially high, for the birth rate has been low almost everywhere. But with the possible exception of a brief period during the heart of the Great Depression, we do not appear in the modern history of our country ever to have had a previous time when nonmetropolitan population growth rates exceeded metropolitan rates. From 1970 to 1974, a net of 1.6 million people moved into nonmetropolitan counties. By contrast, 3.0 million net outmigration took place from these counties in the 1960s, and an even larger number in the 1950s. County population estimates for 1975 are available for thirty-two states at the time of writing and show a continuation of the 1970–74 pattern (U.S. Dep. Commerce 1975a). I expect the net movement nationally into nonmetropolitan areas to be about 1.9 million for 1970–75.

It is my experience that people who are cautious or skeptical about the trend want to know at least three things. Are the data reliable? How widespread is the phenomenon? Couldn't it just be an increased rate of sprawl out of metropolitan areas into adjacent nonmetropolitan territory?

The principal source of current population data is the annual series of estimates for all counties that the Bureau of the Census now makes in cooperation with state agencies (U.S. Dep. Commerce 1975a). There is simply no foolproof method of estimating population change for counties in intercensal years, and some of the estimates will undoubtedly be proven incorrect by the next census, even as to direction of change. But the average quality of the county estimates is good (as can be judged by their degree of correspondence with special censuses that are taken) and has improved with the addition of residential data from the Internal Revenue Service since 1973. (These data are made available to the Bureau of the Census in the form of computerized records of individual income tax returns.) Current estimates may overstate metropolitan populations to some extent, but it is not conceivable that the figures are yielding a wrong signal at the national level. Interview data from the Current Population Reports show the same pattern of growth, although at more modest levels (U.S. Dep. Commerce 1975b). Furthermore, available causal data, such as the Social Security Administration's statistics on covered employment and on location of retired worker beneficiaries, confirm the population data and are based on records

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The discussant for this session was Lee M. Day of the Northeast Regional Center for Rural Development.

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Table 1. Population Change by Metropolitan Status and Selected County Characteristics

		Population					Net Migration			
		Number (1,000)			Percentage Change (%)		1970–74		1960–70	
Item	Number of Counties	1974	1970	1960	1970–74	1960–70	Number (1,000)	Rate[a] (%)	Number (1,000)	Rate[a] (%)
Total United States	3,097	211,392	203,212	179,323	4.0	13.3	2,076	1.0	3,001	1.7
Metropolitan status[b]										
Metropolitan counties	628	153,930	148,809	127,191	3.4	17.0	461	0.3	5,959	4.7
Nonmetropolitan counties	2,469	57,463	54,404	52,132	5.6	4.4	1,614	3.0	−2,958	−5.7
Adjacent counties[c]	969	29,780	28,022	26,116	6.3	7.3	1,010	3.6	−705	−2.7
Nonadjacent counties	1,500	27,683	26,382	26,016	4.9	1.4	604	2.3	−2,253	−8.7
Entirely rural counties	623	4,618	4,353	4,548	6.1	−4.3	190	4.4	−553	−12.2
Characteristics of nonmetropolitan counties in 1970										
Counties with 10% or more net inmigration at retirement ages[d]	360	8,653	7,554	6,340	14.5	19.2	932	12.3	624	9.8
Counties with senior state college	187	9,031	8,434	7,463	7.1	13.0	323	3.8	91	1.2
Counties with 30% or more employed in manufacturing	638	20,143	19,257	18,193	4.6	5.9	356	1.8	−746	−4.1
Counties with 30% or more employed in agriculture	331	2,062	2,057	2,305	0.2	−10.7	−17	−0.8	−412	−17.9
Population density per square mile in nonadjacent counties										
150+	15	1,176	1,124	1,020	4.6	10.2	17	1.5	−10	−1.0
100–149	35	1,929	1,842	1,699	4.8	8.4	18	1.0	−73	−4.3
75–99	61	2,781	2,674	2,568	4.0	4.1	20	0.7	−170	−6.6
50–74	127	4,298	4,099	3,990	4.9	2.7	84	2.1	−313	−7.8
25–49	351	7,764	7,412	7,270	4.8	1.9	176	2.4	−541	−7.4
10–24	405	5,681	5,412	5,562	5.0	−2.7	177	3.3	−584	−10.5
Less than 10	506	4,054	3,820	3,907	6.1	−2.2	111	2.9	−561	−14.4

Sources: U.S. Dep. Commerce 1975a; Bowles, Beale, and Lee.
[a] Net migration expressed as a percentage of the population at beginning of period indicated.
[b] Metropolitan status as of 1974.
[c] Counties adjacent to Standard Metropolitan Statistical Areas, 1974.
[d] Counties with specified 1960–70 net inmigration rate for white persons 60 years old and over, 1970.

rather than estimates (U.S. Dep. Commerce 1974; U.S. Dep. Health, Education, and Welfare). Beyond this, one can always go and see for oneself. Many local journalistic accounts document the change, and in my travels I have yet to visit an indicated turnaround county where the local officials were not aware of the trend occurring.

As measured by the rate of net migration, all but two states show increased net retention or greater acquisition of population in their nonmetropolitan areas in the 1970s as compared with the 1960s. The two exceptions are Rhode Island, where the only nonmetropolitan county had a military base closing, and Connecticut, where the state's two nonmetropolitan counties continued to attract population but at a reduced rate. In the 1960s, thirty-six states experienced nonmetropolitan outmigration. This number is down to eight in the 1970s. Thus, the new trend of population change in nonmetropolitan areas is widespread, affecting every region and subregion of the country.

The third question, concerning metropolitan sprawl, is best answered by looking separately at those nonmetropolitan counties that are adjacent to metropolitan areas and those that are not. The adjacent counties contain slightly more than half of the total nonmetropolitan population, and their population increased by 6.2% from 1970 to 1974. This rate of growth is somewhat higher than that of the nonadjacent counties (which was 4.9%) and has increased since the 1960s. So there is an adjacency effect, as one might logically expect. But it is not an either/or situation. Both adjacent and nonadjacent classes of nonmetropolitan counties have had a migration reversal. The force of the reversal has actually been stronger in the more remote nonadjacent class than it has in the adjacent group. Numerically, the reversal amounts to an average of 369,000 persons annually in the nonadjacent counties compared with 307,000 annually in the adjacent counties.[1] As a result, there is less difference in the migration pattern of the two classes of counties today than there was earlier, although the adjacent group still has the higher rate of growth.

My basic approach to drawing inferences from the data about the nature of the new

[1] These numbers represent the difference between the average annual net migration for each adjacency group in 1970–74 compared with the annual average of the 1960s.

trend has been to classify counties by certain basic functional characteristics and examine the trend in those that are dominated by some feature or function. In this approach, the nonmetropolitan counties that show the most rapid growth are those that can be termed retirement counties. The designation is made on the basis of 1960–70 trends and excludes the additional retirement counties that are now developing, but the results are impressive. In the 360 nonmetropolitan retirement counties total population grew by 14.5% from 1970 to 1974, with a net inmigration of 932,000 people. This is a rate of growth of more than 3% per year. The inmigration to these counties was more than half of total net inmigration into all nonmetropolitan counties. But essentially all retirement counties gained in total population. Thus, the rest of the country contains nearly all of the 600 nonmetropolitan counties that have lost population, as well as others that have grown. Many of the retirement counties have other sources of growth than retirees, such as recreation businesses or manufacturing. Although we all nominally understand that there are more older people than there used to be and that retirement plans have become more generous in both money and age of eligibility, we have not fully anticipated the potential implications of these developments on population distribution. Most retired people do not move, but those who do go disproportionately to nonmetropolitan locations, especially areas accessible to water (whether lake, reservoir, or ocean), scenery, or a favorable climate. They create business and employment, yet are not constrained by the need for employment themselves.

The second most rapidly growing class of nonmetropolitan counties is that where a senior state college is located. These counties include 9 million people, are basically exclusive of the retirement counties, and grew by 7.1% from 1970 to 1974. Like the retirement counties, they were already having population gain in the 1960s. The pace has increased in the 1970s, but there is suggestive evidence that it may have slowed since 1973 with the end of the military draft and the general peaking out of college enrollment rates.

In the 1960s, one of the main economic trends was the decentralization of manufacturing. In that decade, there was little manufacturing growth nationally, but a substantial shift of plants to small city or rural locations took place. The most cited reasons for the shift seem to be utilization of underemployed nonmetropolitan female labor force, lower wage rates, better worker attitudes, less unionization, availability of cheap land, improved transportation, and flight from urban ills in general. In some parts of the country the increase in manufacturing jobs was truly dramatic. For example, in the twenty-three counties of Tennessee that lie on or west of the Tennessee River (exclusive of those that adjoin Memphis) manufacturing employment rose by 98% in the 1960s on a base of 32,000. In twenty-six counties of northern Arkansas—both Ozarks and northern Delta—the growth was 70% on a base of 24,000.

Often this growth took place in areas that had a comparatively small initial proportion of workers in manufacturing and were simultaneously losing farm employment heavily. Thus, the impact of the manufacturing growth on population retention in the 1960s is somewhat masked, for a majority of it did not occur in counties already having a large industrial base where additional nonfarm jobs would automatically be reflected in net employment and population gains.

If one looks at the record of counties that now have a high dependence on manufacturing, such counties (defined as those where manufacturing comprised 30% or more of all jobs in 1970) had a 4.6% population increase from 1970 to 1974. This is higher than their growth of the 1960s and represents a turnaround from outmigration to inmigration. But it is distinctly below the rate of growth being observed in counties with less than 30% dependence on manufacturing. Manufacturing comprised 50% of all growth in nonmetropolitan employment in the 1960s. The subsequent slackening of manufacturing and the surge in trade, services, and other sectors (except government) has seen manufacturing jobs amount only to 3% of nonmetropolitan job growth from 1970 to 1976 (USDA).

As might be expected, counties with high dependence on farming are still having net outmigration. Those with 30% or more dependence as measured by a 1970 industry group of workers had only 0.2% growth from 1970 to 1974 and 17,000 net outmigration. Even so, this is a far lower pace of outmovement than in the 1960s, and counties that continued to have this degree of involvement in the production phases of farming contained just 1 million people in 1970, less than 0.5% of the total U.S. population. The agricultural employment base

is now so small that its trend can have relatively little further effect on the total trend of nonmetropolitan change.

One of the most interesting and significant aspects of the recent trend is the complete shambles that it has made of the former strongly positive association between density of population and growth. If one classifies nonmetropolitan counties by persons per square mile, as in table 1, it is immediately apparent that in the 1960s preexisting high density was almost a guarantee of population growth, and very low density was associated with population decline and heavy outmigration. In the 1970s, the highest rate of growth occurred in the counties with the lowest density, rather than the highest, and there is little difference among other classes. This finding is also consistent with the fact that if counties are grouped by size of largest town, the completely rural group (with no place of 2,500 people) shows the highest recent growth.

Here is convincing, even startling, evidence of a rapid shift down the scale of residence that involves the most remote, least settled, and least urbanized parts of the country. Nothing in the literature of the 1960s foresaw such a change in the association of scale and density with growth.

This feature leads me to note a distinction among the metropolitan areas that is sometimes overlooked in the metropolitan-nonmetropolitan dichotomy that characterizes so much of the public discussion of the trend. If one groups metropolitan areas by size class, those of less than 750,000 population are found to have had increased net inmigration during the 1970s. Only above this size is the movement into the metropolitan areas typically reduced or negative. The small and small-to-medium-sized metropolitan areas are showing the same increased attractiveness to population growth that the nonmetropolitan areas are showing. The major point of inflection from the trend of the past is up within the ranks of the metropolitan areas. The nonmetropolitan reversal is the most extreme aspect of a larger trend.

Press reports on the new trend have occasionally carried back-to-the-farm headlines that had no basis in the content of the story. But there are a couple of agricultural aspects that need mentioning. First is the not-well-enough-known fact that since 1970 the decline in younger farmers has stopped and the median age of farmers is dropping. Persons under age thirty-five solely or primarily self-employed in agriculture rose by 35% from 1970 to 1975 as measured by the Current Population Survey (Beale 1976). The departure of farmers over sixty increased, and median age fell from 53.1 years to 50.4 years.

I have visited agricultural officials in about twenty counties in several states in 1976 and in almost every case have gotten field confirmations of the trend, usually emphatic confirmations. Noneconomic considerations related to attitudes and values are given almost as often as are economic factors as motivating factors in the increased number of young farmers. The result is to introduce more young farm families into the countryside despite some continuation of the trend of farm consolidation. Second, in less commercial farming areas, there is an undeniable trend of entry into farming of people with nonfarm backgrounds. This back-to-the-land phenomenon is difficult to quantify but is commonly reported in news stories and is very much in evidence in areas such as the Ozarks, northern New England, the Upper Great Lakes country, the Blue Ridge Mountains, and parts of the far West. Failure rates are almost certainly high, but some net accrual to the rural population occurs.

Allied to this aspect of the overall trend is the reported trend of occupancy of former farm homes. In the same field visits referred to above, it was consistently reported that the practice of demolishing former farm homes that was so common a few years ago has changed. Such homes are now commonly rented or bought with five or ten acres by people who work in towns (whether metropolitan or not).

Trend data on towns per se are available only through 1973 and are not as reliable as for counties, at least among smaller-size places. But a tabulation of the Census Bureau's estimates for 1973 (not shown here) shows nonmetropolitan towns of 10,000 or more people increasing in population by little more than half the rate of the rest of the nonmetropolitan population since 1970 (Fuguitt and Beale). This is consistent with the growth pattern for counties classed by size of largest place or by density and with the diminished rate of growth in nonmetropolitan urban towns that was found in the 1960s. In many respects the nonmetropolitan towns are experiencing in a micro way the same trends as metropolitan central cities; that is, there is a decay of the central

business district, growth of suburban shopping malls, and a dispersal of people out into the surrounding countryside or villages. The towns continue to annex land and people in states where the laws are permissive, but they find it increasingly difficult to reacquire in annexable areas as many people as they lose to areas too distant to annex. In a very real sense the current trend of population distribution is one of renewed rural residential growth—open country and village. A majority of it occurs in counties that have no places of 10,000 people, and it is especially pronounced in counties that lack any town of even 2,500 people.

As a result, there is a strong likelihood that the total rural population may increase when the next census is taken. In the past two generations, so much growth in rural areas has become urban in character and reclassified as such that there has been essentially no net increase of the rural population. I am rather dubious that the rural population could ever go above 60 million people, but it now appears to be advancing toward such a level.

Presentation of these trend data leads logically to questions about the future. The older I get the more skeptical I become about demographic projections. The record as to fertility, total population, and distribution ranges from poor to terrible. Yet the demand for projections and the comparative painlessness of making them in the age of computers combines—like Shaw's view of marriage—the maximum of temptation with the maximum of opportunity. I simply do not believe that we can foresee societal behavior well enough to say with any confidence how long the current shift of growth patterns to smaller-scale communities will last or how far it will go. Beyond stating that I do not envision the end of great cities or urban dominance, I am content with saying that the current distributional trend is real and substantial (not just a transient and negligible aberration) and has substantial momentum that seems likely to continue at least into the next decade.

All of the current complex of forces that produce the trend essentially favor a continuance over the middle term. Some are the comparatively favorable economic condition of nonmetropolitan areas as reflected by growth of jobs and reduction of the metropolitan-nonmetropolitan income gap; the absence of much further displacement from farming; the revival of mining; continued growth of a retired population oriented toward recreational or climatically favored areas; the downscaling residential aspects of the environmental-ecological movement, butressed by certain nature-oriented and antimaterialistic elements of the youth revolution; the unfavorable image of the great cities in such areas as crime, drugs, pollution, race conflict, school troubles, and fiscal matters; the near elimination of many former rural-urban gaps in material conveniences of living, such as water supply, plumbing, heating, electricity, roads, and communication; the high cost of metropolitan housing; and the emergence of an adequate system of post-high school education in nonmetropolitan areas.

The major potential problem that I foresee is the matter of gasoline costs and supply. The new trend of population is not energy conserving. Rural people use considerably more gasoline per capita and have less in the way of public transportation alternatives during an emergency (Rupprecht). What would happen if there were another oil embargo of greater length? What would happen if the price of gasoline assumed European levels?

A second potential lessening of the nonmetropolitan migration could stem from the low birth rate of the last decade. Fewer families in the coming years will have an incentive to seek smaller communities out of concern for the welfare of their school-aged children, a motivation fairly commonly encountered today.

A final consideration in viewing the overall trend is that it has to be put in world context. Demographic turnarounds of this magnitude rarely occur in national isolation. The present trend is international in character. It may be further advanced here than elsewhere, but slowdowns in urbanization can be measured in a number of the most advanced nations (Wardwell). I had no sooner published on the subject than I received an article by investigators in Sweden on the return to small towns in that country. Social scientists have given little thought to the probable settlement pattern in modern nations beyond the urbanizing period. Once modernization proceeds to the point that rural-urban disparities are relatively eliminated, and urbanization rushes to the point that the urban environment is impaired, is there any further need for or likelihood of additional massing of people? The answer may be "no."

Some would say that the present trend is nothing but an urbanization of life in rural

areas, whatever the location. To some degree this is undoubtedly true. Indeed, the AAEA once heard a presidential address on "The Urbanization of Rural America" (Bishop). But the new trend cannot be simply explained away semantically. It represents a major departure from what was publicly anticipated and will have a variety of consequences. Whatever the style or content of life of former urbanites in the rural and small city environment, the setting is no longer metropolitan urban for them, and the difference is consciously meaningful to them.

The advantages of urbanization are erodible and not without limits in societies where rural areas are no longer isolated and backward or retarded by an urban-oriented value system. Subtly but surely, we have entered a transition in population distribution that does not make this country a rural nation again but that greatly modifies the vision of unbridled megascale urbanism that seemed to dominate our perceptions a few years ago.

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Forces Influencing Rural Community Growth

Kenneth D. Rainey

This paper focuses on three questions. What is happening demographically in the rural areas of the United States? Can the recent growth trend be expected to continue into the future? What does this imply as far as public policy and programs are concerned? The first question has been dealt with very capably by Beale (1975, 1976). There is little room to doubt his statistical evidence. As the latter two questions lend themselves more to nonstatistical arguments and as I have little data, I will concentrate on them.

That this country is at or nearing the end of an era seems certain, but what lies ahead is by no means certain. Several years ago the Virginia Rural Affairs Study Commission published its first report with these words and nothing else on the cover: "Since the industrial revolution, cities have been growing and rural people have supplied the growth." Today that quote would not be accurate. Cities, at least the largest ones, do not seem to be growing any longer, and taken as a whole the nonmetropolitan areas are growing faster than the metropolitan areas.

Twenty years from now will another rural affairs report state: "The decade of the seventies marked the end of metropolitan growth and the beginning of a rural renaissance. A new settlement pattern developed in the United States, one that was unique for a high technology economy"?

The statistics on growth in the seventies suggest three possibilities: (*a*) a change in the functions of metropolitan and nonmetropolitan areas; (*b*) the decline of the city as the major cultural and economic focus (it has happened before; at the end of the Roman era in the fifth century cities could not be sustained by the culture and were thus abandoned); and (*c*) a decline in the utility of our statistical definitions and the continuing homogenization of America. This latter is much less dramatic. If it is merely the definitions, we ought to be able to handle that among ourselves. The homogenization of America, however, might be just as much a cause for concern as the beginning of a new Dark Ages.

What is probably happening is a mixture of all three of the above possibilities. What is happening and what it means will not leap out of the statistics on metropolitan and nonmetropolitan change. Instead, one must step back to look at some of the major forces that will influence the American economy and demography for the next few decades. It is these major national forces that will shape not only how many people will live in the rural areas but also their relative well-being.

First among these forces is the aging of the baby boom. The children born in the post-World War II years have had already a tremendous impact on this nation. Grade schools had to be built to accommodate them, then high schools, and then colleges and universities. Some analysts warn that the biggest challenge lies ahead—having an economy that will not only generate jobs for these young adults as they enter the labor force but also will contain adequate opportunities for upward mobility as this group advances into middle age (Johnston). Moving an inverted population pyramid through hierarchical organizational structures seems quite a challenge. How this can be met is one of the great unknowns of the future. Johnston points out that the annual growth in the labor force in the years preceeding the coming of age of the war baby boom cohorts was about 880,000, of which less than 150,000 were teenage workers. More recently the annual growth has been over 1,700,000, with over 300,000 teenage entrants. The peak lies ahead. To the growing number of new teenage entrants into the labor force one must add the rising expectations of women. This combination is difficult to por-

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tray adequately in statistical terms. There has been a tremendous growth in the measured labor force, an even greater growth in the potential labor force, and a still greater growth in the demand for jobs and careers that offer some upward mobility.

The movement of the war baby boom cohort into the labor force is one of the most important, if not the most important, factors that will shape the future distribution of population in the United States. Where the war babies go will be where the growth will occur. As has been true of past generations, they will doubtless go where the jobs are. Where will the jobs be in such vastly expanded numbers? More important, will economic and political institutions be able to generate them anywhere? Let us not be choosy about rural or urban locations. If they cannot be generated, we may face a social time bomb far more important than the metropolitan-nonmetropolitan distribution of population.

A second trend to be recognized is the continued decline in the birth rate and aging of the population. It seems the birth rate will continue to decline in both rural and urban areas (U.S. Dep. Commerce 1974). Rural areas will not serve one of their traditional functions as supplier of immigrants to the cities. As the population rapidly ages, there will be a substantial shift in the demand for public services. Fewer schools will be needed, but health care needs and facilities for the aged will increase.

Third, the problems of the war babies will be made much more acute if the predictions regarding lower rates of job formation and economic growth in the United States do come to pass. One current debate is whether the U.S. rate of economic growth over the next few decades will be substantially less than it has been in the post-World War II period (U.S. Dep. Housing and Urban Development). An election year may not provide a dispassionate assessment, but some implications of slower growth are troublesome. The United States has done its problem solving out of its growth. It has not gone in for absolute redistribution of wealth, only for changing who gets what shares of the increment in national wealth. Furthermore, the most serious consequence of slower growth is that it will doubtless reflect a lower rate of job formation.

Energy supply and cost constitute a fourth factor. The cost of energy relative to other costs almost certainly will increase. Some supply difficulties and shifts in the various fuel shares of overall energy needs also seem likely. This will have many confusing impacts on rural areas and their development. First, rural areas as suppliers of raw materials for energy will see tremendous activity (a carefully vague word). Appalachia is now having another of its boom periods—lots of jobs, lots of activity. But whether it will have a lasting, favorable impact on the well-being of the Appalachian people is not clear. Second, rural industry has become dependent on relatively cheap oil. Agriculture is now dependent upon both energy uses of oil and petrochemicals for insecticide and fertilizer (Wilson). Availability problems and increased cost not only will require adaptation to new sources and equipment changes but also may severely decrease the profitability of some kinds of production. Increases in the price of gasoline for automobiles will make the rural pattern of long distance commuting very expensive. Increased transportation costs for industry may again tip the production cost balance in favor of more central locations.

The final factor to consider in looking at the future of nonmetropolitan areas is the role of American agriculture in maintaining the world food supply. The huge decrease in rural population due to the mechanization of agriculture is doubtless over. We have more than enough productive capacity to meet our own needs and traditional markets. If the United States was to become a major supplier of antistarvation food reserves to the world, it would mean a substantial increase in production and in the relative wealth of U.S. agriculture, but probably only a modest increase in rural population.

Each of these major forces has more than one possible outcome, of course. It would be mere fortune telling to say which outcome will occur. We have been surprised in the past by shifts in such factors as birth rate and lifestyle preferences. Furthermore, the factors can be combined in a number of ways, offering a sort of do-it-yourself futures kit.

What may be happening is an extension and blurring of the metropolitan outer ring (U.S. Dep. Commerce 1975). The settlement pattern of the United States is developing into a huge Swiss cheese, with two kinds of holes. The first kind of hole is the central cities of the older and larger metropolitan areas, which are emptying like the dust bowl of the 1930s. The other kind of hole in the demographic Swiss cheese is the large and still remote areas in the mountains—the Great Plains and the West. Both of these kinds of holes seem likely to lose population, at least relatively, to the cheese

itself. We have no present statistical term to describe the cheese. It is the fringe of the major urban conglomerations, the smaller and medium-sized metropolitan areas, and the less remote nonmetropolitan regions. Beale is quite correct in saying that much of the 1970–74 growth cannot be explained adequately by saying it is merely nonmetropolitan areas becoming metropolitan (1976). However, an important factor is that all of this fringe area, whether metropolitan or not, is tied to the metropolitan economy for many kinds of services and trade. The growing counties are hooked into the metropolitan areas for most of their supplies, services, and markets.

For future public policy the meaning of all of this can be summed up in three inequalities.

First, agriculture does not equal rural America. For a long time, we have known it is improper to equate the needs of agriculture with those of rural areas, but we continue to do it anyway. Agriculture is an increasingly urban business even when it is done far away from the city. Thirty-six percent of the agricultural employment is in metropolitan areas, and only 12% of the nonmetropolitan employment is in agriculture. From a public policy standpoint, one should be careful about arguments concerning the likely benefits to be achieved through certain public programs for either agriculture or the rural community. The welfare of the two have less and less to do with each other.

Second, industrial development does not equal increased community well-being. Summers's recent work is a very important research finding in the field of economic development. It gets at the mythology of industrial development and shows new manufacturing plants often cost the rural community far more than it gains. The multiplier is much lower than once anticipated. We lack good ways to calculate in advance costs and benefits to different parties. The community sometimes gives away its taxing potential to attract the industry and then must provide facilities to serve it. The labor force commutes in from a nearby metropolitan fringe with a lunch box. A wholesale revamping of both national and state economic development programs is needed. We are paying a tremendous public price to take money out of one pocket and put into another. An even more serious concern is that we have not known what pocket we were putting it into.

Third, growth or increased well-being for rural America does not equal growth or increased well-being for the rural community. Because much of the rural population and rural industry is directly linked to nearby metropolitan regions for supplies, services, and markets, the growth in rural population and even rural employment does not reflect a corresponding increase in the health of rural small communities. This is the final area that public policy should address. These communities are called upon to supply public services but frequently are losing ground economically. Small town business is losing out to metropolitan areas. Rather than filtering its needs for equipment, supplies, or repairs through small town business, primary industries, whether agriculture or manufacturing, increasingly go direct to metropolitan outlets. The retail consumer does the same thing, bypassing the small town store for the shopping centers. Economists do not worry about this sort of thing, because in their view it represents a triumph of the market economy, and they have little enough of that to point to. But this "triumph" represents discontinuity, a growing gap between those communities expected to provide public services and their ability to pay for them. It also represents the increasing ability to some people and organizations to externalize their costs on others.

As Beale pointed out, people are slow to accept the notion that the growth patterns have changed (1976). We knew and loved the notion that people were moving from the country to the city, and it has been very hard to cast off the mental image of that development pattern. If people are slow to accept these changes, they are slower still to change public policy to adapt to them. Agriculture and community development policies are still based largely upon the images of the past—the need to keep people on the farm, even the small and relatively inefficient producer and the need to help depressed areas, which were largely rural. Congress and the state legislatures will have to be busy and effective in the next few years if we are to stop giving out the medicine to cure a sickness the patient no longer has, while ignoring those that now afflict him.

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Economic Implications of the Recent Population Shift Toward Rural Areas

Marion Clawson

Beale has presented clear evidence that a shift in the direction of migration has taken place in the United States in the past few years (1976), and he has given the best available indications of who these people are, in terms of their age, income, occupation, family status, and the like. My task is to speculate on the economic, social, and political significance of these population changes. In the nature of the situation, any remarks must be more speculative and less firmly based on facts than is his statement.

It is well to start by recalling that Americans have always been a mobile people, quite possibly the most mobile large population the world has ever known. The first century of our national existence was dominated by the vast westward tide of migration; the Bureau of the Census has calculated that the center of population in 1790 (when the first Census was taken), was 23 miles east of Baltimore (U.S. Dep. Commerce); by 1890, Turner in his famous essay, using census definitions, concluded that the frontier had vanished. The second century of national history was dominated by the vast rural-urban migration, which built the cities and transformed the nation. Each of these two major migration tides extended to some extent to earlier and later periods. Overlaying and supplementing these two major streams of population movement have been numerous others, smaller in numbers, more localized geographically, more specialized in population characteristics, or with some combination of these factors.

Extensive areas of the United States have lost population persistently. More than a third of all counties have lost population in each decade since 1910, with half losing in the 1940s and 1950s, and a substantial proportion of these counties have lost in most or all these decades. There are extensive areas of the Corn Belt, as well as hill country, mining areas, and other less economically soundly based areas, where the maximum population was reached as early as 1900. Our economic literature is full of theorizing and of empirical studies of growth; decline, at least in population numbers, has been common, yet has had but a small fraction of the professional attention (Clawson).

Still less professional attention has been directed at areas that declined in population for a considerable period of time, then reversed their own trend and grew. The 1930s were generally a period of population growth in many counties that had previously declined, but this was a measure of the greater unemployment and depression in the city than in the home county. There are more than fifteen counties in southern and central Indiana that have lost population in every decade from 1900 to 1930 (and some in earlier decades as well), only to reverse themselves in the 1930s and to grow in population in every decade since then. It is interesting that in central and southern Illinois also about twenty-five counties declined in the same period of decline (1900–30) but have continued to lose in at least two out of three decades since 1940. There appears to be no explanation for these divergent trends within roughly comparable states. The 1960s was a period of population growth in roughly 100 counties in the South, mostly in the Ozarks and other hill country, and some in other parts of the country, which had previously lost population for several decades. Hansen has tried to explain the recent population trends for groups of "turnaround-reversal" and "turnaround-acceleration" counties of the 1960s, but, by and large, the "reversal areas" have had little professional analysis.

Beale (1976) and others are now calling our attention to the recent and general reversal of population growth in relatively rural, or nonmetropolitan, counties as compared with metropolitan ones. He has pointed out that some

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of the increased population is due to greater retention of the natural increase, but some is due to net immigration. While the counties nearer the metropolitan areas have grown somewhat faster, the more remote nonmetropolitan areas have also grown, and faster than the metropolitan areas.

Any analysis of migration or of population changes generally is dependent upon the disaggregation of time and space in the available data. Until fairly recently, analysts were dependent upon the ten-year population census for relatively finer-grained analyses. It is only in comparatively recent times that the kind of relatively fine-grained analysis based on annual data, which Beale has presented (1976), was possible. But the geographic unit of analysis may affect results also, whatever the time intervals used. For convenience in analysis, many have used county data; this seems the best compromise between geographical specificity and manageable amounts of data. Nevertheless, county data may conceal many intracounty shifts in population. For instance, a county may show a relatively constant population over a series of decades, yet the largest town has been growing steadily, obviously at the cost of population loss elsewhere in the county.

Are the recent shifts in population, away from metropolitan areas and toward nonmetropolitan areas, the beginning of a major persistent trend, or will they prove to be a relatively limited episode in national population history? Are they the beginning of a new wave of major population movement, in some degree comparable to the westward and cityward tides of the past, or do they represent primarily a backlash from the rapid—perhaps overly rapid—metropolitan growth of the past twenty-five years? Only time will tell. The changes described by Beale (1976) are too recent and too small for us to draw any firm conclusions.

In some of his writings, Beale has suggested that the recent shift to nonmetropolitan areas has been in a sense "against the current" of income; that is, instead of moving toward higher incomes per person, as migration historically has, people are now choosing somewhat lower incomes and better living conditions (1975). Does this in some degree represent a new attitude toward income and the material aspects of living that income can buy? If so, how far is it a function of the higher average income levels of today; i.e., when one enjoys a good level of living, perhaps he can be more cavalier about further increases in income than he was when he was poorer. It is true, as Beale (1976) and others have pointed out, that opinion surveys have long reported that many people expressed a preference for small town living. Some of us have been unimpressed by these verbal expressions of choice, noting that in practice more people moved cityward than moved in the opposite direction. But maybe the time has now come when a significant number of people are acting as they have long said they preferred to act.

The recent migrations from metropolitan to nonmetropolitan areas involve substantial transfers of income. All migrations involve income and wealth transfers to some extent; migrants bring not only material possessions but also education, skills, and other personal qualities that often enrich the receiving area. But a significant proportion of the recently added population in the nonmetropolitan counties receive pensions or other payments, which were either earned elsewhere in younger years or are a transfer of public funds from taxes paid elsewhere, in either case, to recipients in the receiving area. The nonmetropolitan counties may indeed be the "best" place for such income receivers to live in terms of cost of living and of satisfactions attainable.

The flow of income to the recipient area can be a powerful economic force. Even where the recipients of such transfer payments are numerically only a small minority of the total population of the nonmetropolitan county, this income stream surely spreads throughout the whole community. Its direct recipients buy goods and services, and the provision of such goods and services in turn provides employment and income to many other persons in the community. There is no reason why an income stream based on transfer payments would have a smaller multiplier effect than an equal income stream based on commodity export. As the number and proportion of the total population living on income derived from sources other than current employment (i.e., pensions based on previous employment, public funds under any one of several public programs for the assistance of particular groups in the population) rises, then this sort of income potential for some kinds of areas also rises. If, at the extreme, all persons in the nation whose income did not depend on current employment chose to live in nonmetropolitan areas, non-

metropolitan counties (if one includes the necessary service population) would indeed experience large population increases.

As Beale has pointed out (1975), there has been some tendency for jobs to move away from metropolitan areas also in recent years. How far will the existence of a labor force, or of a potential labor force, in nonmetropolitan areas attract footloose employment there? Some part, perhaps a large one, of the postwar migration of jobs in Florida, California, and the Southwest was the pursuit of a labor force—people had moved to these areas because they wanted to live there and were available for jobs in those locations. It is by no means clear what kinds of employment, if any, would be likely to follow a potential labor force to nonmetropolitan areas. Employment in recreation enterprises, or in some kinds of manufacture such as furniture making, or various kinds of extractive employment (mining, forestry, and agriculture) may well be located in nonmetropolitan areas. Such employment will in turn generate service employment. But, over and beyond these, what kinds of employment would likely follow workers into metropolitan areas? For those who have observed the difficulties and general lack of success of rural areas in attracting manufacturing and other employment in the past, it is hard to visualize what may happen in the future. The level of national employment is obviously a factor here; if jobs seek workers, then migration of employment to areas of surplus workers becomes more likely.

It is hard to estimate what effect this migration from metropolitan to nonmetropolitan areas will have upon the average income per capita and upon content of living per average person in the nonmetropolitan areas. In the past, population loss from nonmetropolitan areas produced older populations, less well educated, with lower average incomes and poorer housing than in nearby counties gaining from immigration (Clawson). But this by no means proves that population increases will have the opposite effect. For the most part, those receiving transfer payments will not have high incomes, yet it is possible that fairly modest incomes on their part might actually lead to increased incomes per capita in the population-recipient areas. This would be true if the average income of the immigrants was above that of the former residents of the area, but it could also be true if the service and other employment created by the flow of immigration was at higher average annual incomes than had previously prevailed in the area. To the extent that the immigrants are a superior labor force, which induces a movement of jobs into a metropolitan area, then one would expect average incomes in the recipient area to rise. The net effect of these various forces is hard to estimate.

It is possible that living costs in the nonmetropolitan areas will be lower and/or living levels higher for a given level of costs. Land rents should be lower and hence the cost of new housing lower, building codes and other restrictions on building may be less costly, and there may be some relative surplus of existent moderate-cost tolerably livable housing in some areas. The opportunity to grow a garden will surely be greater, but the effect of this on net income may be modest indeed. Beale has suggested that transportation costs may be higher in nonmetropolitan areas, since workers will, on the average, have to travel further from home to jobs and will in almost all cases have to rely on personal auto transportation (1976). For some of the older people, the general lack and impracticability of public transportation in many nonmetropolitan areas may become a serious problem, irrespective of costs.

If the people who move to nonmetropolitan areas do indeed enjoy life more there, as they evidently hope to do, then of course important economic values have been created by their move even if we are hard pressed to give such values a quantification.

Increased population in nonmetropolitan areas will create a need for greater public services in such areas. To the extent that such an area has lost population during the past two or three decades, it may have some unused capacity in some forms of public services—schools, for instance. Many, if not most, nonmetropolitan areas have some excess capacity in their transportation networks; that is, somewhat more traffic can be accommodated on present roads, although more people may well lead to a demand for road improvements. Much will depend upon the age composition of the immigrants. Younger couples will create a demand for more schools; older persons will create a demand for more health services. The latter are the more likely to create serious problems for the local governments of nonmetropolitan areas. Persons fifty-five to sixty-five years of age who migrate to such areas may have few health problems now, but

in a decade or more they may create a severe local health problem. Many nonmetropolitan areas have had deficient health services in the past—too few doctors and dentists, hospitals too few and remote from much of the population, etc. One can reasonably question whether typical nonmetropolitan areas are the best places for good or economic health care for older people.

A significant immigration to a nonmetropolitan community, or a significantly larger retention of the community's natural increase in population, will change to some degree the social structure of the area. Outmigration in the past has left many nonmetropolitan areas with fewer young people. It has also probably left the community with a socially more conservative population, one more content with things as they are and less inclined to seek adventure and change. It is conceivable that newcomers (or retained young people) will fit into such a community (in the sociological sense of the term); indeed, it seems likely that many immigrants hope to do just that. But it is also conceivable that social tensions may arise between newcomers and old residents and between older and younger residents. To the extent that many of the immigrants are older and/or that a large proportion of the resident population is relatively older, there may arise sharp differences within the community, on age lines, on such matters as public expenditures for schools versus public expenditures for health services. It is hard to generalize about the social effects of the new population growth in nonmetropolitan areas, but one would expect there to be some effects, even if one is not sure in advance what they will be. Population change, especially population change arising out of migration, always produces social effects.

It is even harder to estimate the probable political effects of population growth in nonmetropolitan areas. Such areas have in many cases lost political power in recent decades, although often they have retained more power than their number of people alone would suggest. Will the newcomers, or the young people who now stay in the nonmetropolitan areas, be more active politically than if they lived elsewhere? Are they likely to be politically more conservative? Their search for what they seem to think are basic values of country and small city life might suggest political conservatism.

One may close by repeating an earlier point: it is too soon yet to have a clear indication of how profound these recent population shifts will prove to be, in terms of future numbers of people, future economic effects, and future social and political effects. The population trend of nonmetropolitan America should be an interesting phenomena to watch during the next decade or more.

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A Migration from Chicago to Bull Shoals—Some Demographic Observations

A. C. Hoffman

I do not know how the demographers do it, but I classify migration in American into three major eras.

The first coincided roughly with the nineteenth century when, for whatever the reasons—to get cheap land, for adventure, or maybe just to get away from a nagging wife or the in-laws back home—many people migrated westward and settled the continent.

The second began approximately with the end of World War I, when farmers were just beginning to get "tractored" off the land, jobs in the cities were opening up as industrialization got well under way, and, after sampling the highjinks of the cities, the returning soldiers did not want to go back to the farm.

The third, as Beale has documented, is just getting under way, but this time the oldsters are in the vanguard. Armed with pension checks and plenty of time on their hands, they are setting out for distant places for a variety of reasons—to find the sun, for fun, or maybe just to try to make a new life for themselves and avoid having to babysit with the grandchildren. I am one of these, and what follows is by way of a report from the new frontier.

Bull Shoals is a little town of about 1,000 people in northern Arkansas, located near the dam on the White River that forms Bull Shoals Lake. It is nationally famous for its bass and trout fishing, but if you knew this already, it means you are neglecting your work and fishing too much.

Most of the people migrating to Bull Shoals are oldsters from up North. But quite a number of younger people are also coming and bringing their needed skills—plumbers, shop keepers, even professional people. Almost without exception, the immigrants in both these age groups are glad they came, and so are most of the natives who were already here.

There is also a discernible third group, much smaller, and comprised mainly of younger people who are seeking a simpler life-style. They do farming of a sort, grow and eat organic foods, do art and handicrafts, worry about the ecology, and sometimes let their hair grow long and tie it up with ribbons. Needless to say, they are regarded with some suspicion by the natives and their status in the community is not unlike that of the hillbillies in Chicago when they started migrating there a generation or so ago.

Development theory teaches that one should begin with the infrastructure. The infrastructure of Bull Shoals consists of the mayor and his council, a post office, one-and-a-half policemen, a volunteer fire department, and a hospital. The next thing to add to the infrastructure is a sewer system, so we can stop polluting ourselves and our beautiful lake. Across the dam and up the road a quarter mile is another little town, Lakeview. It is an exact replica of Bull Shoals, with an identical infrastructure; it is also trying to get a sewer.

To a casual observer, it would make sense to merge these two little towns and combine their infrastructures, thereby saving the taxpayers a little money and giving them better service. But woe to the local politician—or the rural development expert from Arkansas State University—who would come into either town and propose that! Bull Shoals and Lakeview are not unique in this; there are literally hundreds and probably thousands of local county and town infrastructures in rural America that, if efficiency were the only criterion, ought to be consolidated but almost surely will not be.

Community planning in Bull Shoals is, of course, in the hands of the local tradesmen and real estate brokers, who in turn are guided by the "unseen hand of Adam Smith." Since more people mean more business, the community is highly growth oriented. Some oldsters would like to see less growth or even no growth at all, but we have not had much to say about it.

Brave words are being spoken these days

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about rural planning, guided growth, etc., and I wish Godspeed to all planners everywhere. But in Bull Shoals, as in many other rural towns, planning continues to be done mainly by the marketplace. This is not meant to deprecate what the planners are trying to do. They must keep trying if there is ever to be hope for anything more rational from a public standpoint, but it is a long, hard road and involves changing some fundamental values and beliefs in rural America.

The economy of Bull Shoals and its environs is a mixed bag. When I started going there twenty-five years ago to fish, it was mainly agricultural. By Corn Belt standards, most of the farms were small, scraggly, and unkempt, many of them still are, but new things are happening.

As people and capital started coming in from the outside, and some of the natives prospered in their business and professional ventures, land ownership began drifting more and more into the hands of the well-to-do. Now one can drive about the countryside and, after a run of typical Ozark farms, come upon some pretty fancy farm setups by any standard—white fences, good buildings, fertilized pastures, and good beef cattle, often purebreds or the new exotics. As recently as fifteen years ago, farm land in the area was selling for \$30 to \$40 an acre; now it sells for five or ten times that and is still rising. Unfortunately I did not have the foresight to buy any.

Bull Shoals cannot yet be classified as an industrial complex, but it is on the way. A few years ago one of the national pharmaceutical companies (Baxter Laboratories) came into the community with a plant employing 4,000 people. Down the road a few miles is a shirt factory and also a company that manufactures bass boats, which it sells from coast to coast. One can get into quite an argument locally over whether the coming of industry is good or bad. Some call it "The Rape of the Ozarks," but most think it is the greatest thing that ever happened. Certainly from a material standpoint, it has improved the well-being of the community.

If one asks people why they migrated to Bull Shoals, most of them will say that one of the main reasons was to escape the crime and venality of the cities. In this respect, their hopes have not been fully realized.

On a per capita basis, crime in the Ozarks is probably not far behind what it is in Chicago. There are usually a couple of murders a year in the community; recently the Bank of Bull Shoals was successfully robbed by a couple of escaped convicts, and not long ago a shopkeeper in a neighboring town was shot dead in a holdup. The local weekly paper frequently reports up to a half dozen break-ins, and there is a usual spate of brawls and bloodlettings sufficiently serious to call in the police.

In several important respects, however, Bull Shoals is considerably better than Chicago in the matter of law and order. Not that it makes much difference to the victim, but most of the crime (not all of it) is personally motivated in the sense that it results from human passions or drinking too much pop of a Saturday night rather than being perpetrated by organized syndicates or street gangs. So far at least, one can go out during the evening without much fear of being mugged, though one might return home to find that the house had been broken into and the shot gun and fishing gear stolen.

There are no race problems for the simple reason there is not a single black person in Bull Shoals and very few within a radius of 100 miles. If we had the same racial mix as Boston or Birmingham, we would probably do no better than they with the race problem. A year or so ago there was a large offering of Vietnamese refugees from nearby Fort Chaffee. No one in Bull Shoals took any.

Harold Breimyer has reported that, although he was not fully aware of it at the time, the rural community in which he grew up had a social aristocracy with lines as rigidly drawn and impenetrable as the snootiest suburb.

So far Bull Shoals is more democratic than that. Social activities in the town revolve mainly around the Veterans for War, clubs for card playing and bass fishing, the church groups, and Friday night bingo. But this may not last. Several local enterprisers recently built a nine-hole golf course, so we are now in the first stages of developing that sine quo non of American middle-class aristocracy, the "Country Club Set"!

Bull Shoals cannot match Chicago in offering the carnal pleasures, but we do have some local action. There is, of course, pot smoking, and last week's paper reported the arrest of twelve persons for selling narcotics, ranging from marijuana to cocaine. As the prosecuting attorney said at the arraignment, "I would say we have a drug problem comparable with that

of much larger cities." I am not sure whether this will be good or bad for the tourist trade.

We have no expensive night clubs, no topless waitresses, and no porno movies. I have been told, however, that pleasures of the flesh are available on a commercial basis in a nearby town.

Many agricultural economists do a lot of tub thumping about what they regard as the relative inadequacy of rural health care, and for this they frequently put a large share of the blame on the medical profession. This may not be an altogether accurate or complete view of the matter.

It was mentioned at the outset that Bull Shoals had a hospital and a team of doctors, and within a radius of 15 miles are two more hospitals with their medical teams. Not all rural areas are as fortunate in this respect, but I (having been in most of them) know of no county seat in Arkansas that does not have a hospital and doctors who can do the ordinary medical procedures. If there is need for more than this, there is almost sure to be the proper specialist in the nearest sizable town, probably closer in terms of time than I was to my doctor in the Chicago Loop. Local doctors do not do heart transplants, but most of them are fully up to the average standards of the profession.

No one denies that many people in rural areas are not receiving adequate health care, just as many people in the cities do not, and for the same reason—they cannot afford it. Until poverty is abolished, or some form of national health program is established for everybody instead of just the war veterans and the oldsters, there is little that can or will be done about inadequate health care in a basic sense.

Oldsters do not procreate much, so I have had no first-hand experience with the local schools. The children in Bull Shoals, from kindergarten through high school, are bused down the road 7 miles to Flippin. Flippin schools do not have all the frills of a north-side Chicago suburb, and they do not have a football team, but if I had the choice of Flippin schools versus most of those in the inner city of Chicago, it would be Flippin hands down.

For those who equate educational progress with the abolishment of the one-room school house, Arkansas no longer has any. Among the last to go was one about 30 miles from Bull Shoals, a delightful place where the second graders, if so minded, could learn faster by listening to the third graders recite.

No report on life in America in these times is complete without reference to the welfare state. So I drove down to our country seat of Yellville, where people go to get welfare and food stamps, to see how the local chapter was coming along.

Marion is a typical rural county, with a population of about 7,000, a mixed economy, and no town with over 1,000 people. About 12% of the people in the county are receiving the food stamps and 3% Aid-to-Dependent Children. On this particular day, 164 people (about 5% of the total work force) were listed as unemployed, looking for work, and receiving one or more kinds of welfare. To place these efforts into perspective, it would be helpful to compare the money spent annually in the county for welfare with the amounts spent for schools, roads, police protection, etc. Unfortunately, because each welfare program is administered separately, total expenditures were not readily available; most records are in terms of numbers of cases rather than money spent. Anyway, there are perhaps some kinds of statistics the people are better off not knowing.

That sewer for Bull Shoals mentioned at the outset is another important component of the community government spending. The estimated cost of the sewer is about $4 million, 75% to be paid by a federal grant and the remainder by the local people. There are many who say that Bull Shoals cannot afford the sewer, and anyway the federal government should not be running up a big deficit by spending money on sewers. They may be right, but this is a matter of spending priorities. Many of these same people will not bat an eye when they read that Congress is about to authorize construction of a new wing of Air Force bombers, which may eventually cost $90 billion, and I will defend the people of Bull Shoals as being no more hawkish than people anywhere else in America, probably less so.

If only Congress would provide the necessary legislation, all the skills and human resources needed to get our sewer are potentially available in the local area and at far less cost to the taxpayers than under present arrangements. Down the road 15 miles the Army Corps of Engineers maintains a staff with more than the necessary skills to engineer and supervise the construction of a sewer. Having about run out of dams to build, they would probably be glad to get the work. What could be simpler in terms of ordinary common

sense than to use, at least for a major part of the labor, some of those listed locally as unemployed, looking for work, and receiving welfare!

I have mentioned this little matter of Bull Shoals' sewer because it illustrates perfectly the sheer waste and degradation of human beings that goes on everywhere in the nation because we persist under the welfare state in giving the unemployed a dole instead of useful work to do. If something more rational is not forthcoming soon, it will bankrupt us, both morally and financially. For whatever the reasons, professional economists have not been in the forefront of those who have proposed public service employment; agricultural economists, to the extent they have bothered at all to look at the problem of rural poverty and unemployment, have usually ended up wringing their hands and urging the need for more food stamps!

In 1972 Congress passed the Rural Development Act, which provided rather generous funding for research into the problems of rural well-being and development. If in all the research planned or under way with these funds, there is a single project relating to some type of public service employment for rural areas, then I will be surprised and simply delighted to hear about it and to stand corrected.

In conclusion, I love Bull Shoals and am glad I migrated there; but I do not think America can solve all her social and economic problems, or even very many of them, by closing down places like Chicago and everybody going out to the countryside.

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Implications of Rising Energy Costs for Irrigated Farms in the Oklahoma Panhandle

Harry P. Mapp, Jr., and Craig L. Dobbins

As recently as five years ago, research on irrigated crop production in the Oklahoma Panhandle and surrounding area overlying the central basin of the Ogallala Formation focused on irrigable acres and regional share of national production as limits to irrigation development. An aggregate analysis was conducted to determine the economic life of the underground water supply for alternative scenarios regarding the rate of development in irrigated crop production (Bekure, Bekure and Eidman). In addition, bioeconomic modeling was used to determine the effects of alternative means of regulating water use at the firm level (Mapp, Mapp and Eidman). In these analyses, input and output prices, intensity of production practices, and the institutional structure were assumed constant through time.

Several recent economic analyses have focused on aggregate or regional effects of alternative product and input prices in areas to the south of the central Ogallala (Condra and Lacewell; Lacewell, Condra, and Fish). Within the central Ogallala, analysis at the firm level has focused on developing costs and returns for reduced tillage production practices and evaluating the effects of changes in overall energy costs on kilocalories of output (Schwartz; Eidman, Dobbins, and Schwartz). This paper examines the impact of rising natural gas prices on the pattern of irrigated crop production, net farm income, and the quantity of water pumped through time for representative farms under various sets of assumptions regarding water resource situations, crop prices, and tillage practices.

The geographic setting for this analysis is the Oklahoma Panhandle. The area is semiarid, receiving from 15 to 18 inches of rainfall annually. The existence of large quantities of underground water suitable for irrigation, favorable input and output price relationships, and the profitability of irrigated production have resulted in rapid irrigation development over the past decade. The larger profits from irrigated production are obtained at the expense of greatly increased energy inputs, particularly natural gas. In the three Oklahoma Panhandle counties, 91% of the irrigation wells are powered by natural gas (Schwab). Natural gas accounts for about 60% ot total energy inputs for irrigated production (table 1). This analysis focuses on the effects of a change in natural gas price rather than an overall rise in the price of energy-related inputs.

Recharge of the Ogallala aquifer is small relative to rates of water withdrawal and the static water level is declining steadily (Hart, Hoffman, and Goemaat). This analysis accounts for the interaction among rates of water use, water depth, well yield, and pumping costs in determining the optimum organization of production through time.

Discussants for this session were Otto C. Doering III of Purdue University, Ronald D. Lacewell of Texas A&M University, and Duane Harris of Iowa State University.

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Table 1. Inputs, Production, and Net Returns of Production Alternatives

	Irrigation Water (ACIN)	Nitrogen (Lbs.)	Phosphate (Lbs.)	Herbicide (Lbs.)	Insecticide (Lbs.)	Diesel (Gal.)	Equip. Lube (Qt.)	Planting Seed First Crop (Lbs.)	Planting Seed Second Crop (Lbs.)	Labor (Hrs.)	Irr. Fuel[a] (1,000 (Ft.^{3})	Grain Yield First Crop (Lbs.)	Grain Yield Second Crop (Lbs.)	Grazing Yield (AUM)	Net Return[b] ($)	NG KCAL/ Total KCAL of Inputs[c] (%)
Irrigated conventional tillage[d]																
Corn grain	24	200	50	2.0	1.00	14.37	5.25	20		8.06	16.96	7,280			193.51	58.8
Wheat, HI	18	100				10.17	3.99	60		5.67	12.72	3,300		0.8	112.25	64.5
Wheat, MI	12	75				10.17	2.89	60		4.47	8.48	3,000		0.7	105.73	59.2
Wheat, LI	8	50				10.17	2.16	60		3.67	5.65	2,400		0.6	77.43	55.1
Corn silage, HI	24	200	50	2.0	1.00	29.40	6.16	20		11.07	23.04	40,000			80.46	52.8
Corn silage, MI	16	125	50	2.0	1.00	29.40	4.69	20		9.47	11.31	18,750			32.35	47.9
Corn silage, LI	10	100	50	2.0	1.00	29.40	3.60	20		8.27	7.07	13,000			−2.25	38.8
Grain sorghum, HI	24	150		1.5	1.00	16.17	5.35	10		8.07	16.96	6,200		1.4	155.97	62.8
Grain sorghum, MI	16	120		1.5	1.00	16.17	3.89	10		6.47	11.31	5,300		1.2	130.04	56.7
Grain sorghum, LI	11	100		1.5	1.00	12.77	2.78	7		4.80	7.77	4,200		1.0	124.93	52.8
Small grain grazing, HI	18	80	40			6.89	3.70	60		4.86	12.72			6.0	−33.24	69.0
Small grain grazing, MI	12	60	40			6.89	2.60	60		3.66	8.48			5.0	−36.74	64.3
Small grain grazing, LI	8	40	40			6.89	1.87	60		2.86	5.65			3.5	−40.01	59.4
Sudan hay, HI	24	100				13.17	5.18	10		7.23	16.96	10,000			58.63	68.4
Sudan hay, MI	16	100				13.17	3.71	10		5.63	11.31	6,000			−0.11	60.5
Sudan hay, LI	12	80				13.17	2.98	10		4.83	8.48	4,800			−13.33	56.7
Soybeans, HI	24	50		1.0		10.86	5.04	90		6.97	16.96	2,700			176.30	73.4
Soybeans, MI	20	50		1.0		10.86	4.31	90		6.17	14.13	2,400			148.20	71.8
Soybeans, LI	16	50		1.0		10.86	3.57	90		5.37	11.31	2,100			120.02	66.6
Irrigated reduced tillage																
Corn grain	24	200	50	2.5	1.00	13.69	5.20	20		7.46	16.96	7,560			205.75	59.1
Corn silage and rye graze double crop	41	200	50	1.5	1.00	27.00	7.85	20	60	14.07	24.03	40,000		4.1	24.73	56.9
Wheat—two-year rotation[e]	17	100		0.5		5.71	3.46	60		6.80	12.01	3,390		1.0	120.68	75.2
Wheat and sorghum double crop	29	100		1.5	1.00	9.96	0.60	60	7	8.45	20.49	3,000	4,800		258.80	62.6
Three-year rotation, wheat-fallow-sorghum, HI	12	83		1.0	0.33	3.83	2.42	20	2.3	3.4	8.48	1,098	2,067	0.79	107.01	65.6
Three year rotation, wheat-fallow-sorghum, MI	10	80		1.0	0.33	3.63	2.01	20	2.3	2.88	6.83	1,098	1,600	0.66	91.05	62.1
Grazed wheat and sudan hay double crop	36	180		0.5		7.94	7.06	60	10	8.73	25.44	7,000		5.25	5.87	71.4
Dryland production																
Wheat	—	60				5.74	0.34	45		1.13		990		0.35	37.84	—
Grain sorghum	—					6.83	0.41	4		1.33		1,100		0.75	47.48	—
Small grain graze out	—	30	30			5.09	0.31	60		0.93				2.4	−1.19	—

[a] Irrigation fuel requirements assume a 950 gallon per minute well and surface distribution system drawing water from a pumping depth of approximately 325 feet.
[b] Net returns represent the residual to land, labor, machinery, overhead, risk, and management.
[c] Natural gas kilocalories as a percentage of total kilocalories of inputs. Source: Eidman, Dobbins, and Schwartz, p. 4.
[d] HI, MI, and LI represent high level, moderate level, and low level of irrigation.
[e] The two-year wheat rotation alternates conventional and reduced tillage production practices.

Alternative Production Activities

Resource requirements, costs, and returns are estimated per acre for both conventional and reduced tillage methods of production. Each of the conventional tillage crops, except corn for grain, includes three levels of irrigation.[1] The reduced tillage methods of production are based on data compiled by Schwartz and are being used on a limited basis by farmers in the area. All production methods identified can be utilized with minor adaptations in the machinery available on the farm. Thus, the purchase of additional specialized machinery is not necessary. Input requirements, production, and net returns for each production activity are presented in table 1.

Prices and Net Returns

Two sets of crop prices (low and high) are used in the analysis. The low prices are based on 1976 target prices.[2] Crop prices are not expected to return to these absolute levels. However, the price relatives implied by target prices are based on historic series and provide a lower bound to solutions of the programming model. The high set of prices is based on seasonal average price relationships for 1969–73 and provides an upper bound on the programming solutions.[3] Input prices used in the analysis are those prevalent in the study area during early 1976.

The net returns presented in table 1 represent the residual returns to land, labor, machinery, overhead, risk, and management. Residual returns is gross receipts minus variable production costs, interest on operating capital and irrigation investment, and depreciation, taxes, and insurance on the irrigation system. With the exception of labor costs, this represents the net return to be maximized in the short run.

[1] Input-output data for the conventional tillage cropping activities are based on practices of the more efficient producers in the area. Thus, conventional tillage represents somewhat fewer tillage operations than the average for the area.

[2] The low set of output prices based on 1976 target prices are wheat, \$2.29 per bushel; corn, \$1.57 per bushel; grain sorghum, \$2.66 per hundredweight; soybeans, \$3.28 per bushel; sudan hay, \$22.00 per ton, and corn silage, \$6.34 per ton.

[3] The high set of crop prices is based on an assumed wheat price of \$3.50 per bushel. Other prices are calculated based on their average levels relative to average wheat prices during 1969–73. Other prices are corn, \$2.89 per bushel; grain sorghum, \$4.68 per hundredweight; soybeans, \$6.46 per bushel; sudan hay, \$33.60 per ton; and corn silage, \$11.20 per ton.

Representative Farm Situations

Previous studies suggest the economic life of the water supply in the Ogallala Formation differs for different water resource situations (Bekure, Mapp). Thus, representative farm situations are defined for three water resource situations. The first, a poor water situation, assumes 100 feet of saturated thickness and an irrigation well yield of 400 gallons per minute. The second, a moderate water situation, assumes a saturated thickness of 250 feet and an irrigation well yield of 750 gallons per minute. The third, a good water situation, assumes a saturated thickness of 412 feet, sufficient to produce an irrigation yield of 950 gallons per minute. For each water situation, the representative farm is assumed to contain 1,600 acres of land of which 1,440 acres are cropland and three irrigation wells equipped with surface distribution systems suitable for clay loam soils of the study area.

The interaction of rate of water use, decline in the water table, and reduction in well yield is accounted for by equations (1) and (2). The decline in static water level during any specified period is given in equation (1):

$$D_t = V_t/0.2A, \tag{1}$$

where D is the decline of static water level in feet, A is the total number of acres in the farm, V is the number of acre feet of water withdrawn, 0.2 is aerial drawdown coefficient, and t is the period.

Associated with the decline in static water level is a decline in irrigation well yield. This relationship may be expressed as

$$Q_t = \left[\frac{H_t}{H_o}\right]^2 Q_o, \tag{2}$$

where Q_t is the well capacity, H_o is the original saturated thickness in feet, H_t is the remaining saturated thickness, and Q_o is the original well capacity in gallons per minute.

The cost of pumping water during any time period depends upon the initial water situation and prior decisions regarding irrigation intensity. Using equations (1) and (2), pumping costs are adjusted each period to reflect the higher costs associated with reduced well yields and increased lift.

Labor supply on the representative farms is composed of operator labor and one full-time hired man. In addition, the operator can hire up to two additional full-time hired men on an

hourly basis. The operator is assumed to borrow operating and investment capital as needed at 10% and 8% simple interest, respectively. The model contains restrictions on land, labor, irrigable acres, and the quantity of irrigation water the system can pump by month. In addition to the conventional and reduced tillage cropping activities, a livestock activity for purchasing 400-pound stockers to utilize supplementary grazing is included.

Using a recursive linear programming model, optimum organizations are determined for a series of five-year periods based on well yields and pumping costs at the beginning of the period; that is, an optimum organization is determined for period 1 and is assumed to remain constant for a five-year period. At the end of five years, water use is calculated, drawdown and well yield for the following period are estimated, and pumping costs are adjusted. An optimum organization is reestablished and assumed constant for the next five-year period. This procedure continues for ten five-year periods, or for fifty years. Optimum organizations are developed for representative farms in poor, moderate, and good water resource situations for conventional versus reduced and conventional tillage practices, with both low and high crop prices, under conditions of constant and increasing natural gas prices. Only a portion of the results are discussed below.

Results

Rising Natural Gas Price

A series of programming runs were made to determine the potential effects on optimum farm organization, net returns, water use, and pumping costs over time of rising natural gas prices.[4] A comparison of the optimal production organizations during periods 1, 5, and 10 under constant and rising natural gas prices for representative farms using only conventional tillage practices is presented in table 2. As expected, rising natural gas prices increase pumping costs per acre inch and reduce net returns, but the magnitudes of the changes may be surprising. For example, pumping costs rise from $0.99 to $3.24 per acre inch over the fifty-year period with constant natural gas price and from $0.99 to $10.75 per acre inch for rising natural gas prices. Net returns decline by 45% under constant natural gas prices and by 63% under rising natural gas prices.

As pumping costs increase over time, a gradual shift occurs from irrigated to dryland production. One effect of rising natural gas prices is to speed the pace of this adjustment. Under constant natural gas prices, 350 acres of cropland remain in irrigated production in period 10. Under rising natural gas prices, a negative shadow price appears on the irrigation well activities in period 7, indicating an incentive for the producer to disinvest in irrigation facilities; that is, if he were forced to cover both fixed and variable costs in the short run, he would convert to dryland production. Irrigated production remains profitable throughout the fifty-year period under constant natural gas prices. The economic life of the water supply is reduced by at least fifteen years under rising natural gas prices.

Conventional versus Reduced and Conventional Tillage

To offset the decline in net returns caused by rising natural gas prices, producers may wish to consider more profitable reduced tillage production practices. The effects on optimal production organization of introducing reduced tillage practices for the medium water situation and high crop prices are also summarized in table 2. Introduction of reduced tillage activities greatly changes the production organization. For example, when only conventional tillage practices are considered, irrigated activities are limited to corn grain, wheat, sorghum, and soybeans. When conventional and reduced tillage practices are considered in the model, wheat and grain sorghum double crop, the two-year rotation of conventional and reduced tillage wheat, and reduced tillage corn grain are the predominant irrigated activities in the optimum organization. Wheat at the moderate irrigation level is the only conventional tillage irrigated activity in the period 1 solution.

Net returns are about 10% higher in period 1 when reduced and conventional tillage practices are included in the model. However, reduced and conventional tillage practices utilize more water and result in lower well

[4] It is assumed that the natural gas price increases from $0.75 per thousand cubic feet (mcf) in period 1 to $1.75 per mcf in period 2 and then gradually rises to $5.00 per mcf by period 10. These assumptions are arbitrary; $0.75 per mcf represents an average price for early 1976, and natural gas contracts are currently being renegotiated for $1.75–$1.85 per mcf in portions of the study area.

Table 2. Comparison of Optimal Organizations of Production for Conventional versus Reduced and Conventional Tillage, under Constant and Rising NG Prices, Moderate Water Situation, High Crop Prices

	Conventional						Reduced and Conventional					
	Constant NG Price			Rising NG Price[a]			Constant NG Price			Rising NG Price		
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Period	1	5	10	1	5	10	1	5	10	1	5	10
Net returns ($)	155,361	124,385	85,006	155,361	97,000	57,747	172,071	129,444	86,463	172,071	97,430	57,744
Corn grain (ac.)	220.0	127.6	65.5	220.0	132.4	5.8						
Wheat, HI (ac.)[b]	303.3			303.3								
Wheat, MI (ac.)		383.8	196.4		397.2		51.6	164.5	77.6	51.6	154.8	
Wheat, LI (ac.)								52.2	24.6		49.1	
Soybeans, HI (ac.)	196.7			196.7								
Soybeans, LI (ac.)		127.6	65.5		132.4							
Grain sorghum, LI (ac.)		42.5	21.8		44.1							
Corn grain, reduced (ac.)							80.5	13.4		80.5	0.5	
Wheat—two-year rotation (ac.)							187.5			187.5		
Wheat and sorghum double crop (ac.)							210.2	192.5	105.9	210.2	210.2	
Three-year rotation, wheat-fallow-sorghum, HI (ac.)								160.5	75.7		151.0	
Wheat dryland (ac.)	152.7	47.5	637.7	152.7	2.0	1,223.8	720.0	299.6	801.3	720.0	338.5	1,179.4
Grain sorghum dryland (ac.)	567.3	711.9	453.1	567.3	731.9	210.4		557.4	355.0		536.0	248.9
Stockers (hd.)	904	843	1,068	904	826	1,304	826	898	1,104	826	904	1,306
Well capacity (GPM)	750.0	382.8	196.4	750.0	397.2	253.6	750.0	361.0	181.6	750.0	361.5	239.5
Cost/ac. in. ($)	0.99	1.75	3.24	0.99	4.43	10.75	0.99	1.85	3.49	0.99	4.85	11.37
NG price/mcf ($)	0.75	0.75	0.75	0.75	2.97	5.00	0.75	0.75	0.75	0.75	2.97	5.00
Water applied (ac. in.)	15,460	10,166	5,216	15,460	10,549	138	16,399	10,221	5,302	16,399	10,170	0

[a] Natural gas is assumed to rise from $0.75 in period 1 to $1.75 in period 2 and then increase gradually to $5.00 per 1,000 cubic feet in period 10.
[b] HI, MI, and LI represent high level, moderate level, and low level of irrigation.

yields and higher pumping costs over time. By period 10, net returns for conventional and reduced and conventional tillage practices are approximately equal.

Cropping pattern shifts over time, when only conventional tillage is considered, involve a reduction in the number of irrigated acres of corn grain and sorghum and shifts to lower intensity irrigation levels for wheat and soybeans. When both conventional and reduced tillage practices are included, the changes in solutions over time are less orderly. However, under constant natural gas prices, about 284 acres remain in irrigated production in period 10 under conventional and reduced tillage versus nearly 350 acres when only conventional tillage practices are considered in the model. Under rising natural gas prices, a complete shift to dryland production occurs over the fifty-year period regardless of the tillage practices considered. The switch to dryland production is somewhat more rapid under reduced and conventional tillage.

A shift to reduced tillage production practices to offset the effects of rising natural gas prices increases net returns in the short run. However, over time the increased water use combines with rising natural gas prices to reduce net returns to the level achieved under conventional tillage practices.

Low versus High Product Prices

A series of programming runs were made to determine the potential effects on cropping pattern, net returns, water use, and pumping costs of variations in product prices. Table 3 presents optimal production organization for periods 1, 5, and 10 under low and high product prices for representative farms utilizing conventional tillage practices in poor and good water resource situations. The implications of product price variations are quite similar for farms across all three water resource situations. As expected, high product prices encourage more intensive irrigation practices, other things being equal.

In the poor water situation, high crop prices result in increased water use. Consequently, well capacity declines more rapidly, and pumping costs per acre inch increase more rapidly under high product prices. However, high product prices more than offset higher pumping costs, resulting in greater net returns. For low product prices, net returns decline from $67,775 to $42,967 (about 37%) over the fifty-year period. About 130 acres remain

Table 3. Comparison of Optimal Organization for Low versus High Crop Prices, Conventional Tillage, Poor and Good Water Situations

	Poor Water Situation						Good Water Situation					
	Low Prices			High Prices			Low Prices			High Prices		
Column	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Period	1	5	10	1	5	10	1	5	10	1	5	10
Net returns ($)	67,775	50,112	42,967	141,919	88,856	70,948	64,716	60,481	48,477	158,856	133,305	90,990
Corn grain (ac.)	88.8	58.3		133.3	50.6	23.7	2.3	2.3	67.2	118.4	215.0	86.7
Wheat, HI (ac.)[a]										192.5		
Wheat, MI (ac.)				399.8	151.6	71.2					391.9	260.2
Wheat, LI (ac.)	399.8	174.8	90.1				457.5	457.5	389.3			
Sudan hay, HI (ac.)	38.4	38.7	30.0				39.1	39.1	38.6			
Grain sorghum, LI (ac.)		19.4		44.4	16.8	7.9			81.3		40.0	28.9
Soybeans, HI (ac.)	94.9	0.2					221.0	221.0	9.9	409.1	73.0	
Soybeans, LI (ac.)				133.3	50.5	23.7						86.7
Wheat dryland (ac.)	534.7	915.9	1,110.1		779.7	1,034.1	486.7	486.7	557.9	549.0		473.3
Grain sorghum dryland (ac.)	283.4	232.8	209.7	729.3	390.9	279.3	233.3	233.3	295.8	170.9	720.0	504.2
Stockers (hd.)	1,280	1,289	1,306	823	1,122	1,220	1,305	1,305	1,286	1,057	807	991
Well capacity (GPM.)	400.0	174.7	90.1	400.0	151.6	71.2	950.0			950.0	518.5	260.2
Cost/ac. in. ($)	0.77	1.58	2.93	0.77	1.80	3.65	1.05	1.46	2.32	1.05	1.79	3.37
Water applied (ac. in.)	8,528	3,942	1,051	10,616	4.024	1,890	9,959	9,959	6,786	16,125	12,057	6,909

[a] HI, MI, and LI refer to high level, moderate level, and low level of irrigation.

under irrigation, 90 acres of which are in wheat at the low irrigation level. Under high crop prices, the decline in net return is from $141,919 to $70,948, slightly more than 50%. Nearly the same number of acres remains under irrigation but in more intensive activities, such as corn grain and wheat at the moderate irrigation level.

The level of product prices appears to be a very important factor in determining the length of time over which producers will find irrigation profitable. For the poor water situation, a decline in product prices from high to target price levels would reduce the length of time horizon over which an irrigator could recover both fixed and variable irrigation costs by 50%. In the moderate and good water situations, the length of time horizon over which irrigation is profitable is reduced by 30% and 10%, respectively.

Conclusions

Rising natural gas prices have several potential effects. First, they increase the cost of pumping irrigation water and, other things being equal, reduce the level of net returns associated with irrigated crop production. Second, the pattern of irrigated crop production and the level of water use over time are similar for both constant and rising natural gas prices. Shifts from high to moderate levels of irrigation occur both under constant and increasing natural gas prices due to changes in the water table and pumping costs. Third, the shift from irrigated to dryland crop production occurs more rapidly under rising natural gas prices than under constant prices. About a two-thirds reduction in net returns accompanies rising natural gas prices and the return to dryland production. This result holds across water resource situations and for alternative tillage practices.

Adoption of reduced tillage production practices increases the level of water use under irrigated crop production. The optimum organization of production shifts from conventional tillage corn grain, wheat, sorghum, and soybeans to wheat and grain sorghum double crop, a two-year rotation of conventional and reduced tillage wheat, and reduced tillage corn grain. Net returns are higher during initial periods under reduced tillage technology. However, higher water use rates and the declining water table combine to increase pumping costs significantly and equalize net returns.

This analysis suggests that producers in the Oklahoma Panhandle have good reason for concern regarding the level of crop prices. Net returns under low crop prices are only 40% to 50% of net returns under high crop prices. In the poor water situation, the time horizon over which producers will find it profitable to irrigate under high crop prices is approximately twice as long as the time horizon under low crop prices. We have heard much discussion the past two years regarding the effects of changes in input prices. This analysis suggests farm operators, as well as those financing operating inputs, machinery purchases, and land, have a vested interest in the level of product prices.

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Farm Management Implications of Reducing Agricultural Pollution Related to Cotton Production in Mississippi

David W. Parvin, Jr.

Sunflower county is located in the heart of the Mississippi Delta. Agricultural pesticides applied to the five major crops in this county total an estimated 3,997,440 pounds of active ingredients (unpublished estimate provided by Arthur). This amounts to 9 pounds per acre for every acre in the county.

Cotton is grown under numerous production strategies in Mississippi. However, cotton pesticide problems in Mississippi can be discussed by considering three cotton production situations: the sandy soils of the delta, the clay soils of the delta, and nondelta cotton production region (primarily the northern portion of the state).

A large percentage of the cotton grown in Mississippi is grown on the sandy soils of the delta. The cost of producing solid cotton on that soil resource under usual input practices (six-row equipment) is estimated to be $267.10 (Parvin et al.). Solid cotton grown on the sandy soils of the delta currently requires 34.02 pounds of pesticides per acre, 6.25 pounds of herbicide, 25.26 pounds of insecticide, 1.08 pounds of fungicide, and 1.43 pounds of defoliant. Cotton grown on clay soil in the Mississippi Delta requires higher herbicide rates per application. The nondelta cotton producers in Mississippi face more severe insect infestation (primarily boll weevil) than the delta cotton producers. Consequently, they apply additional insecticide applications.

Per acre returns to cotton production vary by region of the state and soil type (table 1). Total specified expenses vary about $10; however, differences in expected yield result in return estimates varying from approximately $95.00 to slightly more than $200.00.

What has been the effect of efforts to reduce agricultural pollution on cotton producers in Mississippi? The major pollutants are insecticides, herbicides, and soil erosion. Fungicides and defoliants are also listed as pesticides or pollutants. Fertilizer is occasionally listed as a pollutant but will not be discussed here. Ginning is a portion of the production process that has been identified as contributing to air pollution.

Regulatory Activities

The organochloride insecticide, DDT, has been banned. Mercury has been banned as a seed treatment. Pesticide applicators must be licensed. Field reentry standards have been established. The labeling of pesticides is now more difficult and expensive (Hamman). However, considerably more regulatory activity has been underway. Cotton ginners have been threatened with increased air pollution control standards. There has been the threat that other organochloride insecticides (especially Toxaphene) would be banned. The organophosphorus insecticide, Methyl Parathion, has been under attack. The organic arsenic herbicides, MSMA and DSMA, have also been under attack.

To date, the major effect of pollution-related activity on cotton production in Mississippi has been psychological rather than real. Most insect pests were highly resistant to DDT before it was banned. Numerous substitute seed treatment materials already existed for mercury when it was banned. The licensing of pesticide applicators and the establishing of field reentry standards have not measurably affected Mississippi cotton producers. However, there is confusion on the part of farmers. No one seems to know what material or activity might be banned or restricted next. However, everybody seems to know that most pollution-related activity is in the area of insecticides, insect resistance to

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Table 1. Estimated Cost and Net Return per Acre, Three Production Situations, Cotton, Usual Input Practices, Six-Row Equipment

		Delta-Sandy		Delta-Clay		Nondelta	
Production Situation	Price ($)	Quantity (Lb.)	Amount ($)	Quantity (Lb.)	Amount ($)	Quantity (Lb.)	Amount ($)
Cotton lint	0.55	730.0	401.50	550.0	302.50	550.0	302.50
Cotton seed	0.06	1,132.0	67.92	853.0	51.18	853.0	51.18
Total income			469.42		353.68		353.68
Total specified expenses[a]			267.10		258.99		257.06
Returns above specified expenses			202.32		94.69		96.62

[a] Excludes land, management, and general farm overhead charges.

currently available insecticides continues to develop, stiffer standards covering the labeling of pesticides have significantly reduced the availability of new insecticides, and insect control on cotton in Mississippi is still heavily dependant upon insecticides.

Ginning

State air pollution standards and compliance dates have been established for cotton gins in Mississippi and all other states in the Cotton Belt. (This section is based on a 1974 study by Wilmot, Looney, and McCaskill.) All compliance deadlines have passed. However, in view of the extreme seasonality of the ginning operation and continuing economic plight of most ginners, air pollution control boards have adopted a "go-slow" policy on enforcement.

Although air pollution control standards have not been enforced, the threat of air quality standards has had an effect. Some ginners with inadequate volumes, already facing uncertain futures, have elected to cease operation rather than to make even moderate outlays for new pollution control equipment. Consequently, some older low capacity gins have been replaced by newer, higher capacity plants. However, even the newest plants are not up to anticipated standards. What are the alternatives? Presently, there are none. Should the regulations be enforced, ginners will have to comply or cease operation.

Fungicides

Fungicides are applied as a seed treatment and as a hopper box treatment at planting. In Mississippi, seed treatment materials are generally Cemosan and Terracost L21. These two materials amount to approximately 0.08 pounds of fungicide per acre. Soil treater XXX is applied as a hopper box treatment at the rate of 1.00 pound per acre. The purpose of these materials is to help insure a stand in cool, damp weather. Fungicides are a recommended production practice.

Defoliants

Most of the cotton acreage in Mississippi receives a defoliant treatment. Some of the acreage is double treated each year. The most popular materials are DEF or FOLEX applied at the rate of 1.30 pounds per acre. (1.43 pounds assumes 10% of the acreage is treated twice.) Defoliation is a recommended production practice, and it is unlikely that producers will not apply defoliant.

Erosion

Currently, no erosion control standards are in effect in Mississippi. However, pressure does exist to enact some standards. Research indicates that relatively flat land is also subject to erosion problems, which is true for sandy and even clay soils of the Mississippi Delta. While soil movement and loss cannot be stopped altogether, the processes of erosion and pollution can be reduced.

Mississippi Agricultural and Forestry Experiment Station (MAFES) is attempting to play a part in specifying the list of tillage operations that will be acceptable. Recommended tillage operations will vary by crop and by soil types. There are no recommended set of practices except for the delta soils. Apparently, erosion can be reduced from 15 tons per acre-year to approximately 5 tons per acre-year on sandy soils and from 13 tons per acre-year to 7 tons per acre-year on clay soils. (One acre inch of topsoil weighs 166 tons.) However, the tillage techniques that are currently being con-

sidered are not appropriate for approximately 75% of the cotton acreage in the state. Currently, MAFES does not have the technology to specify a set of recommended tillage practices for each specific land resource that could be used for cotton production.

Herbicides

At the present time no cotton herbicides have been banned. Table 2 lists the most common weed control program used by cotton producers on sandy soils in the Mississippi Delta, specifying eight trips over the field not counting planting and hoeing. Table 2 indicates 6.52 pounds of herbicides. Herbicide costs are $22.37 per acre, and total cost per acre including application cost are reported at $51.35. Are there alternatives to this program? Cotton production in Mississippi is currently not possible without the application of some herbicides. For example, farmers with severe weed control problems typically use eleven trips over the field for weed control. However, there is a group of cotton producers in Mississippi that have managed their weed problems continuously to the extent that they have relatively clean fields, and this group typically uses only five trips over the field for weed control. They closely supervise their weed control operations to insure proper timing and placement of materials. However, their clean fields are the result of the proper use of chemical herbicides for the previous several years. MSMA is the most popular grass herbicide. Under current technology cotton cannot be produced profitably on most fields in Mississippi without MSMA and cannot be produced in Mississippi utilizing chemical herbicide weed control alone. Producers are still dependent to some degree on hoe labor and mechanical cultivation.

There are indications that new packages of technology may be forthcoming in the future relative to weed control. However, none of these bundles of technology are suitable for use by cotton producers in Mississippi today, who are moving toward a system of weed management for the entire farm. This conceptualized weed management program will probably utilize a wide variety of herbicides on crops.

Insecticides

Table 3 lists current insect control cost per acre for usual input practices in the Mississippi Delta. These costs apply to sand and clay soils. Excluding planting, nine trips over the field are required. Bidrin is applied (usually in May) to control thrips. The other eight applications are applied in July, August, and September to control the bollworm and tobacco budworm. This program specifies 25.26 pounds of insecticides. Total insecticide costs are $32.57. The total per acre cost of this insect control program is $43.02.

The boll weevil is an economic pest in the nondelta area of Mississippi. Under usual input practices in the nondelta area of Mississippi, twelve applications excluding planting are required. The "usual input practices" in-

Table 2. Weed Control Costs per Acre, Usual Input Practices, Sandy Soil, Six-Row Equipment

Operation	Technical Herbicide (Lbs.)	Herbicide Costs ($/Acre)	Total Costs ($/Acre)
Disk and apply Treflan	0.50	3.47	6.47
Disk and incorporate Treflan	0	0	2.15
Plant and apply Karmex (DL)	0.32	1.62	1.62[a]
Cultivate	0	0	2.34
Cultivate and post direct MSMA	1.03	1.13	4.02
Cultivate and post direct Cotoran + MSMA	1.29	3.65	6.54
Hoe	0	0	4.60[b]
Cultivate and post direct Cotoran + MSMA	1.29	3.65	5.82[c]
Cultivate and post direct Karmex WP + MSMA	1.09	1.75	3.92
Hoe	0	0	4.60
Cultivate and post direct Lorox	1.00	7.10	9.27
Totals	6.52	22.37	51.35

Note: Eight trips not counting planting and hoeing.
[a] Herbicide only.
[b] Two hours of labor.
[c] Lower total cost due to faster performance rate of cultivation.

Table 3. Insect Control Costs per Acre, Usual Input Practices

Operation	Times Over	Insecticide	Technical Insecticide (Lbs.)	Insecticide Costs ($/Acre)	Total Costs ($/Acre)
Plant	1.0	Di-Syston	0.01	—[a]	—[b]
		Temik	0.30	4.74	4.74[b]
Apply insecticide—ground	1.0	Bidrin	0.20	0.81	1.61
Apply insecticide—air	6.0	Toxaphene	12.00	—[c]	
		Methyl Parathion	6.00	15.70	
		Fundal	0.75	6.09	28.29
Apply insecticide—air	2.0	Toxaphene	4.00	—[c]	
		Methyl Parathion	2.00	5.23	6.88
Insect scouting	—	—	—	—	1.50
	9.0[d]		25.26	32.57	43.02

[a] Di-Syston is seed treatment—cost reflected in price of seed.
[b] Application cost charged to planting operation.
[c] Toxaphene and Methyl Parathion are sold as blended material.
[d] Nine trips over the field excluding planting.

secticide program for the nondelta region is 0.30 pound of Temik applied at planting (mid-May), 0.20 pound of Bidrin in late May, five applications of 0.25 pound of Guthion plus 0.20 pound of Fundal during July and August, five applications of 2.00 pounds of Toxaphene plus 1.00 pound of Methyl Parathion during August and September, and one application of 0.25 pound of Guthion in September. This program specifies 18.00 pounds of insecticide at a cost of $35.83. The total cost of the insect control program including application and scouting is $47.04 (Parvin, Hamill, and Toney).

No DDT was sold in 1972, so that 1973 was the first year without DDT. It was speculated that the banning of DDT would result in increased insecticide applications by most producers (Cooke); it has not (Cooke et al., Parvin et al.). However, the use of Methyl Parathion has increased approximately 300% (USDA). The number of applications has not increased for two reasons. First, the Cooperative Extension Service and others have had massive education programs dealing with integrated pest management, especially scouting techniques. Second, insecticide costs have increased drastically.

The current approach to cotton insect management in Mississippi is a prescription (scouting) insecticide program. This alleviates many of the problems associated with regularly scheduled insecticide applications. Environmental pollution is reduced, as are cost and insecticide selection pressure, and natural enemies are preserved during most of the season to combat new pest and pest resurgence problems. The speed with which scouting techniques have been adopted has undoubtedly been increased by efforts to reduce pollution. However, the basic control technique is still chemical insecticides.

Currently, the most serious cotton insect in Mississippi is the tobacco budworm. Problems encountered in tobacco budworm control in Mississippi during the 1975 crop year have emphasized the seriousness of the situation. Many producers failed to control the tobacco budworm with repeated applications of recommended insecticides, and costs were in excess of $60.00 per acre. The situation is very serious. If present practices continue, insecticide resistance in the tobacco budworm populations could eliminate cotton production in Mississippi, just as it was eliminated from northern Mexico (Lukefaher).

Since the number of approaches to tobacco budworm control other than insecticides are extremely limited, each one should be fully investigated to determine its potential. Four areas of research seem to offer the most promise for tobacco budworm control: insecticide testing, sterile release, host plant resistance, and pest management.

The past program of unilateral reliance on chemical pesticides not only resulted in some serious control failures but also had some undesirable side effects. The current practice of scouting cotton fields, using insecticides only when necessary, and relying on natural enemies as much as possible appears to be inadequate. The concept of integrated insect pest management appears to offer promise of long-term solution to the cotton insect problems (Harris, Laster, Newsom). However, a complete integrated insect pest management

system for cotton in Mississippi has only been conceptualized, and most of the visualized components are only in the research stage. Basic research needs to be completed, and agricultural economists need to evaluate the contribution of specific pest management strategies to an integrated cotton insect pest management program.

Research Implications

If a reasonable compromise to the problem of agricultural pollution related to cotton production is ever to be found, research scientists of all disciplines must be involved. The current emphasis has been on cotton insecticides, which is especially true at MAFES. However, pollution associated with cotton production involves gins, fungicides, defoliants, herbicides, and tillage (erosion), as well as insecticides. New systems of cotton production, which are both biologically and ecologically sound, will need to be developed. At a minimum these new systems of cotton production will probably include new insecticide, herbicide, and erosion components, which result in the reduction of the pounds of pesticides used per acre and vastly improved erosion control standards.

A problem of this magnitude requires the system approval to research management. However, research designed to investigate all of the ramifications of agricultural pollution related to cotton is probably beyond the capabilities of any single experiment station. What can MAFES (or other experiment stations) do to assist cotton producers meet the problems associated with reducing agricultural pollution? First, they need not await regulatory action and be forced to react in a hurried fashion. Much regulatory activity is predictable. For example, three cotton pesticides—MSMA, Toxaphene, and Methyl Parathion—are almost certain to be banned as soon as alternatives are available, and they may be banned sooner. Agricultural economists should evaluate the impact of banning these pesticides. By performing the analysis now, the study could be conducted in an unhurried fashion, and the results of the study might have an impact on the regulatory agency. Some erosion control regulations are certain to be forthcoming in the near future. Researchers should immediately move to develop erosion control alternatives and attempt to influence or even assist the selected regulatory agency to write erosion control standards.

Finally, partial systems analysis is the appropriate approach to use to investigate the problem of agricultural pollution relative to cotton. This approach involves identifying the key components of the system to be studied and concentrating research resources in those areas and is the approach taken at MAFES. Because insects are a serious problem on cotton in Mississippi and because insecticides make up approximately 74% of the pesticides applied to cotton in Mississippi, MAFES has concentrated on alternative strategies of insect management. A plant growth model is being developed to simulate the effect on yield of weather, plant nutrition, and insects. However, only the very rudimentary stages of using systems methods to develop insect management techniques are in process. The real impact of this technology on pest management is probably ten to fifteen years in the future.

Summary

What current alternatives does the Mississippi cotton producer have available for maintaining net income in the face of the current emphasis on a cleaner environment and pesticide regulations? Almost none. Soybeans are the competing crop for cotton in Mississippi. Net return figures for soybeans comparable to those reported in table 1 are delta-sandy soil—$73.34, delta-clay soil—$71.59, and nondelta soil—$53.80 (Parvin et al.; Parvin, Hamill, and Toney). Cotton producers will be sacrificing considerable net income if they shift to soybeans. There are no new cotton varieties that are near release that could significantly increase yield and reduce costs per pound of lint.

Four components of cotton production (weed control, insect control, harvesting, and ginning) make up over 80% of the cost of producing cotton in Mississippi. Regulatory activity associated with pesticide production is almost certain to increase weed and insect control costs (Day). Enforcement of pollution standards in gins will undoubtedly increase ginning costs. Harvesting costs total 24% of total costs. Reductions in the cost of harvesting cotton will require a technological breakthrough.

The development of resistance by the tobacco budworm to all available insecticides is dominating cotton production in Mississippi. Other than the proper use of an ovicide, the

only alternative available to Mississippi cotton producers is to increase the rate of Methyl Parathion. Unless this problem is solved in the next two to four years, the farm management implications of reducing agricultural pollution related to cotton production in Mississippi may not be relevant. When this immediate problem is resolved, we must move toward developing systems of cotton production that are consistant with current and anticipated regulations. This may involve drastic genetic modification of the cotton plant and will involve new systems of weed, insect, and erosion control.

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Inflation and Crop Profitability: How Much Can Farmers Pay for Land?

Warren F. Lee and Norman Rask

The purchase of a parcel of farm land can be one of the most difficult investment decisions confronting farm operators. Compared with other production inputs, land is purchased infrequently and usually involves a large, long-term financial obligation. The land investment decision is especially critical today, when many are questioning the ability of farm income to support current land values at "normal" commodity prices.

Fairly stable relationships existed during the 1960s between land values, net returns to farming, and the general rate of inflation (see table 1). However, during the 1970s and especially since 1972, land prices have escalated sharply, net farm income has been very volatile at high levels, and nonland production costs have increased faster than the general price level (consumer price index). These recent trends raise serious questions not only of magnitude but also direction of movement for these important determinants of how much farmers can pay for land.

We accept the proposition that prospective buyers must evaluate investments and make decisions based on present conditions with appropriate allowances for future anticipated trends. In this paper, we have not attempted to guess the future direction nor magnitude of these important variables but have developed a framework for analyzing farmland investments. A capital budgeting decision model developed by Lee for evaluating farm real estate purchases is used to test the land price sensitivity of a set of decision variables. Specific case situations are analyzed by comparing buyers with different characteristics, each facing favorable and unfavorable economic trends. These specific situations are then compared to illustrate how much farmers can afford to pay for land under specified conditions and expectations. For purposes of analysis, a Corn Belt farm situation is assumed, although the general results and conclusions would apply to most parts of the country.

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A Model for Evaluating Land Prices

The traditional formula used by real estate appraisers to estimate land values is $V = I/r$, where V is the estimated value, I is the expected residual net return to land, and r is the capitalization rate (Suter, pp. 247–52). For example, if a parcel of land is expected to produce a net rental income of \$50 per acre and the opportunity cost of money is, say, 8% per annum, then the estimated land value is $V = I/r = \$50/0.08 = \$625$ per acre. As Crowley suggests, this formula provides an accurate estimate only if three conditions are met: (*a*) the investment is expected to produce the same annual net rent over time, (*b*) the capitalization rate used to discount future net rent remains constant, and (*c*) an infinite or very long investment time horizon is considered. Crowley goes on to show that these three conditions are rarely met and that the apparent rate of return on farmland, given by $r = I/V$, generally underestimates the actual rate of return.

Despite the obvious shortcomings of the traditional income capitalization approach, the price that a prospective purchaser can afford to pay for a parcel of land is strongly influenced by his income expectations and opportunity cost of capital. Land purchases are generally financed with borrowed capital, so that credit terms such as interest rates, down payments, and the length of the loan amortization period must be taken into consideration. An important but often overlooked variable is the extent to which anticipated annual net returns and long-term capital gains will be reduced by income taxes. A buyer's bidding position is

Table 1. Index of Farm Land Values per Acre, Net Returns to Farming, and Production Costs

Year	Consumer Price Index	Index of Farm Land Values: U.S.	Index of Farm Land Values: Corn Belt[a]	Index of Farm Net Returns: U.S.	Index of Farm Net Returns: Corn Belt[a]	Index of Farm Production Costs
	1967 = 100					
1960	89	69	70	94	79	92
1961	90	70	68	98	92	93
1962	91	74	70	99	92	94
1963	92	77	73	96	93	95
1964	93	82	78	86	76	94
1965	94	86	82	105	114	96
1966	97	94	92	114	119	99
1967	100	100	100	100	100	100
1968	104	107	106	99	92	102
1969	110	112	112	115	113	106
1970	116	117	114	113	99	110
1971	121	122	117	116	104	115
1972	125	132	125	149	125	122
1973	133	150	142	271	262	146
1974	148	187	185	213	149	172
1975	161	214	216	213	145	188
1976[b]	170	245	280	—	—	—

Sources: U.S. Dep. Labor 1960–73, 1974–75; USDA 1971, 1973, 1975a, b.
[a] Estimated from published individual state data for Iowa, Missouri, Illinois, Indiana, and Ohio.
[b] Estimated.

also influenced by the length of the planning horizon and his expectations about future trends in land prices and the rate of growth in net returns to land.

This suggests that the land purchase decision can be evaluated using standard capital budgeting procedures. (Capital budgeting techniques are covered in Aplin and Casler; Hopkin, Barry, and Baker, chaps. 9, 10, and 11; and Nelson, Lee, and Murray, chap. 3.) In other words, purchasing a parcel of land is an acceptable investment alternative if the present value of net cash receipts is equal to or greater than the present value of the cash outlays (i.e., if the net present value is equal to or greater than zero) or if the yield or internal rate of return exceeds the opportunity cost of capital.

Capital budgeting is a widely accepted method of evaluating investments in short and intermediate term depreciable assets such as machinery (Aplin and Casler). Hopkin, Barry, and Baker have illustrated the potential use of capital budgeting for evaluating real estate investments as well (chap. 12).

The major cash inflows associated with an investment in real estate consist of the annual net returns to the land and the returns from selling the land at the end of the planning horizon. Cash outlays consist of the down payment, principal, and interest payments on the mortgage loan and income taxes.

The annual net returns to land should be regarded as a residual return to land after all production costs except interest charges on land debt have been deducted from gross receipts. In areas where there is an active rental market, real estate appraisers generally use the net rental method (landlord approach) to estimate this residual return. In areas where renting is less common, a budgeting approach can be used. A discounted cash flow model was developed with the objective of providing the individual land buyer with a method of evaluating a parcel of land using his particular discount rate, income expectations, credit terms, and income tax situation (Lee). The following notation is used: $\bar{P}$ is average price per acre from recent sales of comparable parcels; CC is the buyer's opportunity cost of capital after taxes; n is the buyer's planning horizon in years; ANI is expected annual net returns per acre before taxes; GNI is expected annual rate of growth in annual net returns per acre; MTR is the buyer's marginal income tax rate (combined federal and state tax rate based on estimated taxable income after the parcel is purchased); DP is the proportion of the purchase price paid down; IR is the nominal rate of interest charged on the mortgage loan; t is

the amortization period on the loan; *INF* is the expected annual rate of inflation in land values; T^* is the tax rate that will apply to capital gains income in year n when the parcel is sold;[1] and P^* is the maximum bid price, given values for the preceding eleven variables.

The maximum bid price (P^*) or the price that gives a net present value of zero is given by

$$P^* = \left\{ \sum_{t=1}^{n} \frac{(1+GNI)^t}{(1+CC)^t} (ANI)(1-MTR) + \frac{(1+INF)^n}{(1+CC)^n} (\bar{P})(1-T^*) \right\}$$

$$\div \left\{ DP + (1-DP)\left[\frac{(1+CC)^t - 1}{CC(1+CC)^t}\right]\left[\frac{IR(1+IR)^t}{(1+IR)^t - 1}\right] - (1-DP)(MTR)(IR) \right.$$

$$\left. \left[\frac{IR(1+IR)^t}{(1+IR)^t - 1}\right] \sum_{i=1}^{t} \frac{1}{(1+CC)^i} \left[\frac{(1+IR)^{t-i+1} - 1}{IR(1+IR)^{t-i+1}}\right] - \frac{T^*}{(1+CC)^n} \right\},$$

where $t \leq n$ (for details concerning the mathematical derivation of this equation, see Lee).

Although considerably more complicated than the traditional appraisal formula, this equation includes most of the major, economic variables that affect the land purchase decision.

Application

"Basic Case" Example

The input data for the "basic case" represent budgeted 1976 cost and income data for Corn Belt farms. Annual inflation rates for net returns and land values are set at 5%, closely approximating pre-1972 rates (table 1). A first mortgage loan for 75% of the purchase price at 10% interest is assumed. Again, these approximate 1976 Corn Belt values. The loan is repayable in equal annual installments over a twenty-five-year period.

The income stream from the investment will be subject to a 30% marginal tax rate, and the capital gains tax will amount to 25% of capital gain when the property is sold at the end of the twenty-five-year planning horizon. The investment must yield a minimum after-tax rate of return of 10% per annum.

The input data for the basic case can be summarized as follows: $\bar{P}$ is \$1,000 per acre; $CC = 0.10$; n is twenty-five years; *ANI* is \$70 per acre per year; *GNI* is 0.05 per annum; $MTR = 0.30$; $DP = 0.25$; *IR* is 0.10% per annum; t is twenty-five years; *INF* is 0.05 per annum; and $T^* = 0.25$.

The solution for the maximum bid price (P^*) given these values for the eleven input variables is P^* is \$1,172 per acre. In other words, under these assumptions farmers can bid up to \$172 per acre above average price of comparable farm sales in this area and still earn the required 10% after-tax rate of return.

Sensitivity Analysis

The basic case was used as a point of departure for examining the response of the maximum bid price to changes in the eleven input variables. The range over which each variable was examined reflects either the entire possible range (e.g., 0 to 1 for the down payment) or a reasonably comprehensive range (e.g., 0.06 to 0.14 for the rate of interest on the mortgage loan). In every case, values for all variables other than the one being examined were fixed as specified in the basic case.

Table 2 summarizes the sensitivity of the maximum bid price to changes in the input variables. In general, the three variables related to expected returns have the greatest effect on the maximum bid price. As *INF* is increased from 0 to 12% per annum, the maximum bid price increases from \$966 to \$2,344 per acre. The variable P^* is also very responsive to changes in values of expected annual net income per acre (*ANI*) and the ex-

[1] Since only half of capital gains income is taxable, T^* is equal to half the marginal tax rate that will apply in the year the parcel is sold. The variable T^* was substituted for $MTR/2$ to allow for the possibility that sale of the property will result in a significantly higher taxable income and hence a higher than usual tax rate in year n. It is also influenced by special provisions in the income tax law, such as those that provide for postponement of the capital gains tax when the farm is sold on a land contract. Such provisions could have the effect of reducing the value of T^*.

Table 2. Sensitivity of Maximum Bid Price (P^*) to Changes in the Input Variables

Input Variable	Range of Values of Input Variable	Corresponding Range in Maximum Bid Price (P^*)
Terms of mortgage financing		
Interest rate (IR)	0.06–0.14 per annum	1,423–976
Down payment (DP)	0–1.0	1,262–964
Opportunity cost of capital (CC)	0.06–0.14 per annum	1,647–885
Land prices and inflation		
Average price of land ($\overline{P}$)	\$500–\$1,500 per acre	1,026–1,317
Expected rate of inflation in land values (INF)	0–0.12 per annum	966–2,344
Income and tax variables		
Income per acre (ANI)	\$30–\$110 per acre	669–1,674
Growth in net income per acre (GNI)	−0.03–0.05 per acre	727–1,172
Marginal tax rate (MTR)	0–0.4	1,274–1,126
Capital gains tax (T^*)	0–0.25	1,233–1,172
Time horizon and loan amortization period (n, t)	10–40 years	1,058–1,251

pected rate of growth in net income per acre (GNI). The buyer's opportunity cost of capital (CC) is also an important determinant of the bid price. A prospective buyer who is content with a 6% after-tax rate of return on his investment can bid up to \$1,647 per acre. However, the maximum price that corresponds to a 14% rate of return is only \$885 per acre.

The terms of financing appear to be fairly important. High down payments and/or high interest rates cause significant decreases in the maximum bid price. As the interest rate (IR) is increased from 6% to 14% per annum, the maximum bid price drops to \$916 from \$1,423 per acre. A purchaser who can borrow the full amount of the purchase price at 10% per annum can bid up to \$1,262 per acre, while the buyer paying cash can earn the 10% opportunity cost of capital only if he can buy the parcel for \$964 per acre. This leverage effect will occur only if the opportunity cost of capital exceeds the after-tax rate of interest on the mortgage. In the basic case, the after-tax cost of capital is 10%, and with a 30% tax rate the after-tax rate of interest on the loan is 7%. Thus, for values of CC less than 7%, P^* would be highest for a cash purchase (DP = 1). In addition to the tax deductibility of the interest payments, inflation also encourages the use of credit because the value of the land and the income are increasing while the loan is being repaid with "inflated dollars."

Some variables used in the analysis have a comparatively minor effect on the maximum bid price. The value of P^* is relatively insensitive to changes in the marginal tax rate (MTR) because the annual net returns are largely offset by tax deductible interest payments on the mortgage loan. The small response of P^* to changes in the capital gain tax rate (T^*) occurs because the tax liability is discounted from twenty-five years into the future.

Analysis of Bidding Potential According to Buyer Characteristics

Four levels of possible economic trends (inflation) are considered for each of six buyer characteristic situations to study their relative bidding positions.

Economic Trend Levels

The two variables considered here are the expected annual growth rates in net returns (GNI) and land values (INF). Both have been at historically high levels since 1972. These two variables are related over time in that high net returns are very quickly capitalized into increased land values; however, while net returns are highly volatile from year to year, land values present a more uniform growth pattern over time and are notably sticky to down side movements in response to declining net returns. This behavior conditions the establishment of trend levels for the analysis. First, recent history would indicate that land prices are not likely to experience an absolute decline over the life of an investment. Thus, a lower boundary for INF is set at zero. On the other side, it is reasonable to assume that land value increases cannot maintain present levels over a twenty- to forty-year period. An 8% growth rate was selected for the boundary on the high side.

For the net return variable it is conceivable

that a return to more normal world production levels, and hence a buildup in world food supplies, coupled with a continued increase in nonland production costs could lead to a slightly negative trend in net returns when compared to present high levels. A lower boundary for growth in net returns is established at −3% and the high boundary was set at 5%.

Four specific trend alternatives were evaluated: (*a*) $GNI = -0.03$ and $INF = 0$; (*b*) $GNI = 0$ and $INF = 0.03$; (*c*) basic case values of $GNI = 0.05$ and $INF = 0.05$; and (*d*) $GNI = 0.05$ and $INF = 0.08$.

Farm Real Estate Buyer Characteristics

Bidders for farm land enter the market representing a broad spectrum of financial positions ranging from the initial land acquisition with little equity through add-on purchases by established farmers. Correspondingly, they bring to the investment decision different levels of operating efficiency (income generating potential), planning horizons, income levels (tax obligation), and initial equity positions (down payment). While each individual investor will have a unique set of circumstances, it was possible to specify six general cases that span most individual situations. Characteristics of the six cases examined are shown in table 3.

Case A portrays the young farmer making his initial land purchase. This purchase is assumed to be of modest size, therefore some size-related operating diseconomies would exist. The buyer would be at an early stage in his productive career and therefore would have a longer planning horizon. The smaller size would also result in less income, therefore a lower tax bracket. Three subcategories are specified for this initial purchase situation based largely on source of additional income. In case A1, income from the farm operation alone must support the purchase entirely and a low tax bracket is assumed. In case A2, off-farm income will increase the tax rate above that assumed in case A1. In case A3, additional land rented will result in some size economies. However, a modest size operation is still assumed, and some income reduction from the basic case occurs. The marginal tax rate is the same as in case A2.

Case B describes the situation of an absentee landlord. Size is assumed adequate for "normal" operational efficiency. Some reduction in income is expected to result from separation of management and operation. A higher marginal tax rate and shorter planning horizon are assumed.

Case C is the basic case described earlier. It assumes a complete farm purchase of adequate size representing normal or average conditions for all variables. Case C would represent an established farmer changing farms or a new entrant with sufficient equity to purchase an economic sized unit.

Case D typifies an established owner-operator who is purchasing an add-on unit. Some gains in size economies are assumed along with a shorter planning horizon and a higher marginal tax rate, compared to case C.

Table 3. Relative Bidding Potential for Assumed Real Estate Buyer Situations

	Initial Land Purchasers					
	No Additional Sources of Income	Additional Off-Farm Income	Additional Income as Tenant on Other Land	Absentee Landlord	Basic Case	Add-On Established Operator
Variables[a]	Case A1	Case A2	Case A3	Case B	Case C	Case D
Planning horizon	30	30	30	20	25	20
Income per acre (*ANI*)	$50	$50	$60	$60	$70	$75
Marginal tax rate (*MTR*)	0.10	0.20	0.20	0.35	0.30	0.35
Down payment	0.20	0.20	0.20	0.25	0.25	0.25
Loan amortization period (t)	30	30	30	20	25	20
Economic conditions			Maximum Bid Price ($/Acre)			
$GNI = -0.03, INF = 0$	404	393	461	484	521	569
$GNI = 0, INF = 0.03$	575	565	653	681	734	787
$GNI = 0.05, INF = 0.05$	976	960	1,108	1,010	1,172	1,169
$GNI = 0.05, INF = 0.08$	1,244	1,249	1,397	1,169	1,470	1,454

[a] Variables not shown were as specified in the basic case ($\overline{P}$ = $1,000, $CC = 0.10$, $IR = 0.10$, and $T^* = 0.25$).

Results

Interpretation of the results (table 3) should be based on relative changes in the maximum bid price (P^*) between specific case situations rather than on absolute values. The estimated maximum bid prices in table 3 demonstrate that anticipated future trends in land values and net returns to farming should have crucial impact on the current economic value of land. Depending on buyer characteristics, there is a two-and-one-half to a three-fold increase from the least favorable to the most favorable economic trend assumptions. Farm buyer situations also can create differential bidding potentials, though these differences become narrower on a percentage basis under favorable economic trends. Regardless of economic trends, however, established farmers and those able to purchase complete economic units (cases D and C, respectively) are clearly in a superior bidding situation. Farm transition data for the Corn Belt confirm this potential. In 1975, for example, 70% of the units purchased were added to established operations. An additional 22% were complete farm units, and only 8% were purchased as part-time units (Farm Real Estate Market Developments).

This analysis, however, does not explicitly account for the important issue of buyer behavior or, more specifically, his ability to bear risk and his willingness to support high land prices in the face of uncertain future trends in net returns and land values. Harris and Nehring have developed a similar model that does include variability in income per acre, the buyer's initial wealth position, and degree of risk aversion along with many of the variables included here. Their conclusions are generally similar to ours, although they note that "the largest farms may not have the greatest bidding advantage after all. A combination of higher marginal tax rate and diseconomies of size may cause (census) Class 0 farmers to have a lower maximum bid price than either Class I or Class II farmers" (p. 168).

The results in table 3 also fail to explain recent Corn Belt land sales in the $2,500 to $3,000 per acre range. Presumably, such prices are based on a more optimistic outlook, so the established operator case (case D) was changed to reflect a favorable outlook over a shorter time horizon. The time horizon n and loan repayment period t were set at ten years. The cost of capital (CC) was reduced to 8%, and equal growth rates were assumed for net income per acre (GNI) and land prices (INF). The average going price per acre ($\bar{P}$) was increased to $2,000 per acre to reflect the assumption that a buyer is unlikely to pay $2,500 to $3,000 per acre if all recent sales have been at only $1,000 per acre. Values of all other variables are as specified in case D (table 3). Values of GNI (= INF) were then increased to yield values of P^* in the $2,500 to $3,000 per acre price range.

The results indicate that while farmers who pay $2,500 to $3,000 for Corn Belt land may be overly optimistic in view of long-run trends, their assumptions are by no means unrealistic in view of the recent past. A 9% per annum rate of growth in both net returns and land prices produces a maximum bid price of $2,592. At 11%, the maximum bid price is $3,053. In other words, when the going price is $2,000 per acre, bid prices approaching $3,000 per acre can be justified on expected values of GNI and INF that are considerably less than actual values since 1972.

Concluding Observations

This modest attempt to synthesize the position of a prospective farmland buyer in a capital budgeting framework indicates that expectations regarding future economic trends and financial position at time of purchase are major determinants of the maximum bid price. We agree with Harris and Nehring, who conclude "The issues of ownership and control cannot be completely resolved until more accurate and complete specifications of the important parameters are made" (p. 169).

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Research Needs and Priorities in the Food System: An Industry Viewpoint

Richard T. Crowder

For professional economists, the subject of this paper implies a gap between the subject matter interests of industry economists and emphasis of current academic research, a lack of communications between those doing research and those in industry who are impatient for answers to constantly changing problems, or both. While the nature of institutional research and the nature of economics training have been perennial themes of industry sessions at annual meetings, increasingly there are similar challenges coming from professionals in academia and government.

Robert A. Gordon, in his presidential address to the American Economic Association, said, "the mainstream of economic theory sacrifices far too much relevance in its pursuit of ever-increasing rigor" (p. 1). His challenge to the profession was "relevance with as much rigor as possible, not rigor regardless of relevance" (p. 12). This challenge is precisely the one industry economists have expressed for some time.

There have also been similar challenges from the leaders of the American Agricultural Economics Association. Bonnen, in his presidential address, stated, "There is evidence that we are failing also to update our conceptual base at a pace sufficient to keep up with the major changes in agriculture" (p. 756). Bottum, in his fellow's address, stated, "We need today in our universities, more individuals and groups with the ability and the courage to tackle fundamental issues facing U.S. citizens" (p. 765). Neilson, in his presidential address in 1974, said, "In the past decade, I believe that we have overinvested in the development and refinement of quantitative methods. We have spent too little time and energy on discovering and tackling the emerging economic and social problems that most trouble our society" (p. 869).

When only that minority of our profession who call themselves industry economists were questioning the relevance of the research of the profession, it could be dismissed as coming from a maverick group of the profession that perhaps did not appreciate the rigor of academic research. However, when it is brought into question by such professionals as those quoted above, it is time that all of us, as professionals, start listening. It is time for those in industry to insure that we are communicating our needs properly and effectively.

The objective of this session is to discuss research needs and priorities in the food system from an industry viewpoint. By no means would it be possible to delineate and rank all research needs of the food industry in a single session. Each of us has an endless list of needs and priorities. My objective is not to present a laundry list of needs ranked on some ordinal basis but to discuss basic procedures and key issues. Specifically, I want to (*a*) comment on criteria for good research, (*b*) identify some of the research needs in the food industry, (*c*) comment on the extent to which the profession is meeting these needs, and (*d*) finally, recommend measures to span the gap that has been identified.

The panel discussants for this session were Charles French of the National Academy of Sciences, Morton Sosland of Sosland Publishing Company, John Morrissey of Super Valu Stores, and Bill Helming of the Livestock Business Advisory Services.

Richard T. Crowder is vice-president and corporate economist of the Pillsbury Company.

The comments and suggestions of Paul Baumgart, Charles Erickson, Ted Rice, Bruce Scherr, and Ed Williams resulted in a substantial improvement of an earlier draft of this paper. However, since all comments and suggestions were not followed, the final paper and any errors therein are the responsibility of the writer.

Criteria for Research

Historically, research by the agricultural economics profession has made many significant contributions to the food industry. Despite this historical performance, there is a tendency for many in the profession to drift away from fundamental criteria in structuring and carrying out research. I think there are two reasons for this.

First, professional rewards and training encourage an emphasis on rigor at the expense of relevance. Let us face it—professional rewards and recognition of those who developed and expanded quantitative techniques have encouraged what Neilson referred to as an overinvestment and refinement of such models. Without the professional rewards and recognition, the pursuit would not have been as intense as it has been. In graduate programs, the emphasis is definitely on rigor, and with this training, the young professional, by nature, carries forward those things for which he has been duly rewarded in graduate school.

Second, the profession is slow to adjust to a changing environment. Therefore, research tends to lag the needs of decision makers, public and private. Once a new concept or program receives professional recognition, there is a "bandwagon" effect that is difficult to slow. For example, there has been a major shift in the location of cattle feeding and beef slaughtering in the United States. With the development and popularization of spatial equilibrium models and with a shift occurring in cattle feeding, a plethora of "optimum location of cattle feeding" studies were made. With the major shifts behind us, studies on the optimum location of cattle feeding continue. While we are after-the-fact studying shifts in the location of cattle feeding, there has been a major shift taking place in the meat industry that has yet to be studied properly, the shift to centralized breaking of cattle. The meat packing and retail industries have been in the midst of this change without any broad-based support from academic research. It is this type of inconsistency that results in the questioning of the relevancy of our research.

To overcome this problem, I recommend that the following criteria be applied to all research.

(*a*) The research must be problem oriented. This does not mean that we do not need theoretical as well as applied research. Quite the contrary, we need both. New problems require new tools and methods of analysis. As the system changes, new theories are needed to explain the operation of the system. Problem-oriented research is research that will improve the decision-making process or will improve the methods of observation, measurement, and interpretation of data that should be used in decision making, public or private. It is not applying a popular quantitative technique to obsolete data.

(*b*) The problem must be real. Research should not be done on a problem that does not exist. I was recently told of a potential study on the location of new lamb slaughtering plants. U.S. lamb slaughter has been declining for fifteen years, and in the past year I learned of four lamb slaughtering operations that have closed. To me, the real problem is one of lamb supply and demand and logically research should be directed to these areas and not on the location of new plants.

(*c*) Assumptions must be realistic and explicit. Two of the most frequent weaknesses of research are that assumptions are not stated explicitly and consequently a potential user does not know if or how the results apply to his particular problem, or that the problem is many times assumed away.

(*d*) The research results must be usable. There are three elements here: the proper technique must be applied to the problem, reliable data must be available on a timely and repetitive basis, and the results must be updatable as conditions change.

(*e*) Finally, the results must be timely. The results of the research must be available for use before the decision requiring the results has to be made. A time objective should be built into every research project.

Industry Orientation

To put in perspective the comments that follow in research needs and priorities, it is important to discuss the industry orientation to research. While there is variability in research emphasis from company to company and, to some extent, from industry to industry, the orientation is toward one goal—better decision making. In a firm, most decisions are based on expected supply, demand, price, and policy variables. Consequently, industry's greatest need is in assessing the future patterns of product demand, input costs, product prices, and input prices and in the policy decisions that influence each of the others. In addition, we concentrate on applied, short-term

problems rather than theoretical, long-term problems.

Because of this orientation and the fact that most company economic research groups are not staffed to be self-contained, industry is dependent on and looks to university and government researchers to fill three basic needs: theoretical research, long-term research, and well-trained people. To put it another way, we look to the public researchers to supply those needs that span company and industry boundaries.

Theoretical Research

Despite the persistent call for applied and relevant research, industries must face the fact that theoretical research and new techniques and methods of analysis are needed. We do use quantitative techniques in research that were developed in academia. We do use economic theories that were formulated by the theorist as a starting point for our analyses. If we reflect properly on the source of our frustrations, it is not necessarily found in the rigor of theoretical research but in the fact that while theory and technique are lagging our needs, the academic community is applying already-developed theory to problems that do not exist or at least are not involved in our decision-making needs.

Long-term Research

The time demands of those in industry for short-term answers are such that we do little long-term macrotype research. Our focus is on short-term company or industry problems. However, for many strategic decisions we need an evaluation of the long-term growth and shifts in the food industry. For example, plant location studies require a projection of long-term availability and location of raw materials. As a basis for such a projection, we evaluate production trends based on such "public" studies as optimum farm organizations and interregional studies. We also use analyses of long-term shifts in product demand and population shifts. Economies of scale dictate that such studies be done at the academic level for use across industries. Many of us in industry have made good use of such analyses.

People

No output from the academic system is more important than well-trained people. While the subject of training has been discussed at two AAEA meetings in recent years, I want to make one point. The primary deficiency of those we interview is a lack of understanding of the decision-making process and how economic research relates to it. I believe that this stems, in part, from the orientation of the research being done at the graduate level.

With this background, I now discuss needs and priorities as I see them.

Needs and Priorities

When we teach economic theory, static and dynamic analysis are separated. Unfortunately, many research efforts do not anticipate and, in many cases, do not keep up with the dynamics of our environment. This has been particularly true during the past four to five years. The environment just passed us by. Industry has been faced with a decision-making environment that it has not seen before and has had nowhere to turn for help. While everyone has his own priorities and an endless list of needs, there are three areas to discuss: risk analysis, market analysis, and policy.

Risk Analysis

For years, with the exception of that part of production economics that made appropriate distinctions between risk and uncertainty and calculated variances and covariances among returns from alternative farm enterprises, the primary emphasis of risk analysis and management was in using the futures market in inventory management. In this case, the teaching was that futures markets were reserved for commodities possessing certain characteristics, one being that the commodity must be storable. Of course, the market, and not research, has long since made these concepts obsolete and ineffective.

This obsolescence was brought about by a drastic change in the operating environment. We went from an environment of surplus commodities and stable prices to one of low stocks and volatile prices. With the exception of some commodity support prices and supply controls, we went from a relatively free market to one of price and margin controls. We went from a market where exports were promoted to one where exports were controlled, where the Soviet Union was not a factor to one where it is a swing factor, where farmers

had to concern themselves with not only cost minimization but also with the marketing of their crops and livestock, and where procurement in the food industry changed from primarily a physical process to an economic process.

In such an environment, new needs developed for measuring risk, determining acceptable risk levels for a particular business, and management tools for managing risk within the constraints of the first two needs.

Obviously, we, as a profession, did not offer to producers, processors, financiers, and distributors of agricultural commodities the decision tools needed to manage in such an environment, particularly the tools needed for measuring risk and determining acceptable levels of risk. The abstract concepts of risk averters and risk lovers are not sufficient for an individual firm. The individual firm must make specific, quantitative decisions concerning risk levels. If we had provided the appropriate tools, we would not have seen the severe financial losses and, in some cases, bankruptcy in the food industry. We would not have seen, and still see, major corporations reporting severe financial downturns as a result of volatile commodity markets. What went wrong? What can we do to avoid repeats? In terms of what went wrong, I think traditional models and our thinking with respect to the application of those models quickly became outdated. In terms of what can be done to avoid repeats, we need to expand our concepts of risk and risk management.

At Pillsbury, risk has been broken down into three categories according to the nature of the business. These categories are (*a*) risk associated with product held for inventory or merchandising, (*b*) risk associated with the erosion of finished product margins, and (*c*) risk associated with physical availability of the commodity.

The management of each risk varies. For the first type of risk, traditional hedging or cross-hedging models are used. For the second type, we have developed a modified game theory model illustrated in table 1. In this model, we attempt to assess the outcomes of alternative procurement and product inventory strategies, given alternative market outcomes and strategies by competition. Procurement decisions are based on the probabilities and magnitudes of the gains and losses of each strategy.

Table 1. Procurement Strategy Model

	Company Strategy and Market Outcome[a]			
	Market Up		Market Down	
Competitor Strategy	Long	PDS	Long	PDS
Long	G	LL	L	GG
PDS	GG	L	LL	G

[a] PDS is price date of shipment, G is gain as a result of strategy, and L is loss as a result of strategy.

While the model is presented in simplified form, there is a broad spectrum of inputs that go into the model. These include the likelihood of alternative competitor strategies and the likelihood of alternative market directions. In turn, the likelihood of alternative market directions is a function of our assessment of government policy, weather, foreign demand (particularly the level and timing of Soviet demand), and the standard errors of our forecasts.

In managing risk, we have a specific dollar level of risk that we are willing to assume and specific procedures for measuring the risk that we are willing to assume. Our measurement of risk is based on historical price levels, absolute price levels, and the errors associated with our forecasts. The error probabilities associated with forecasts are based upon a forecasting track record and not from standard errors of models we estimate. Four years ago I argued at the AAEA meeting that forecasting track records (the difference between actual price and the forecasted price) and not standard errors of equations should be the basis for assessing the probabilities of alternative price ranges (Crowder, pp. 781–82). Based on articles since then, obviously I did not make a strong impression.

While our model and methodology needs refinement, it is better than traditional approaches to the problem. With the increase in risk associated with weather, policy, and variation in foreign and domestic demand, there is an increasing demand for improved risk management models by decision makers, and I think it is a challenge to the profession to develop models that are not only theoretically sound but are also models that can be understood and applied by everyone in the food industry from producer to retailer, including the agricultural policy makers.

Market Analysis

Because agricultural economists have been making market analyses for years, this area for research emphasis might be overlooked. However, our past record and our current reputation in this area leaves something to be desired. The poor performance in market analysis over the past four to five years implies that too much time has been spent refining quantitative techniques and too little time on analyzing changes and structural shifts in the food industry.

Historically, market analyses have been price and quantity oriented. Price analyses have been made on the basis of a given supply, prices or supplies of competing products, and a demand shift variable such as income. Supply analyses have primarily been cobweb analyses—current supplies are a function of lagged prices.

Based on the work done, these simplistic descriptions of the system analyzed with complex quantitative models are not nearly as effective in helping the decision-making process as are simplistic models that properly reflect the market system and process. Let me illustrate with a simple model.

As major users of boneless beef, one of the major inputs to Pillsbury's procurement strategy is the cow kill during a year. Based upon an analysis of the decision-making process in the beef industry, we know that the number of cows killed in a given year is not a function of last year's or this year's cow prices but of the current and historical profitability of the cow-calf enterprise and of the number of cows available for slaughter. Figure 1 depicts the model used to forecast cow slaughter in a given year. The percentage of the 1 January cows slaughtered during the year is a function of current and lagged profits to cow-calf operators.

There are four important points about the

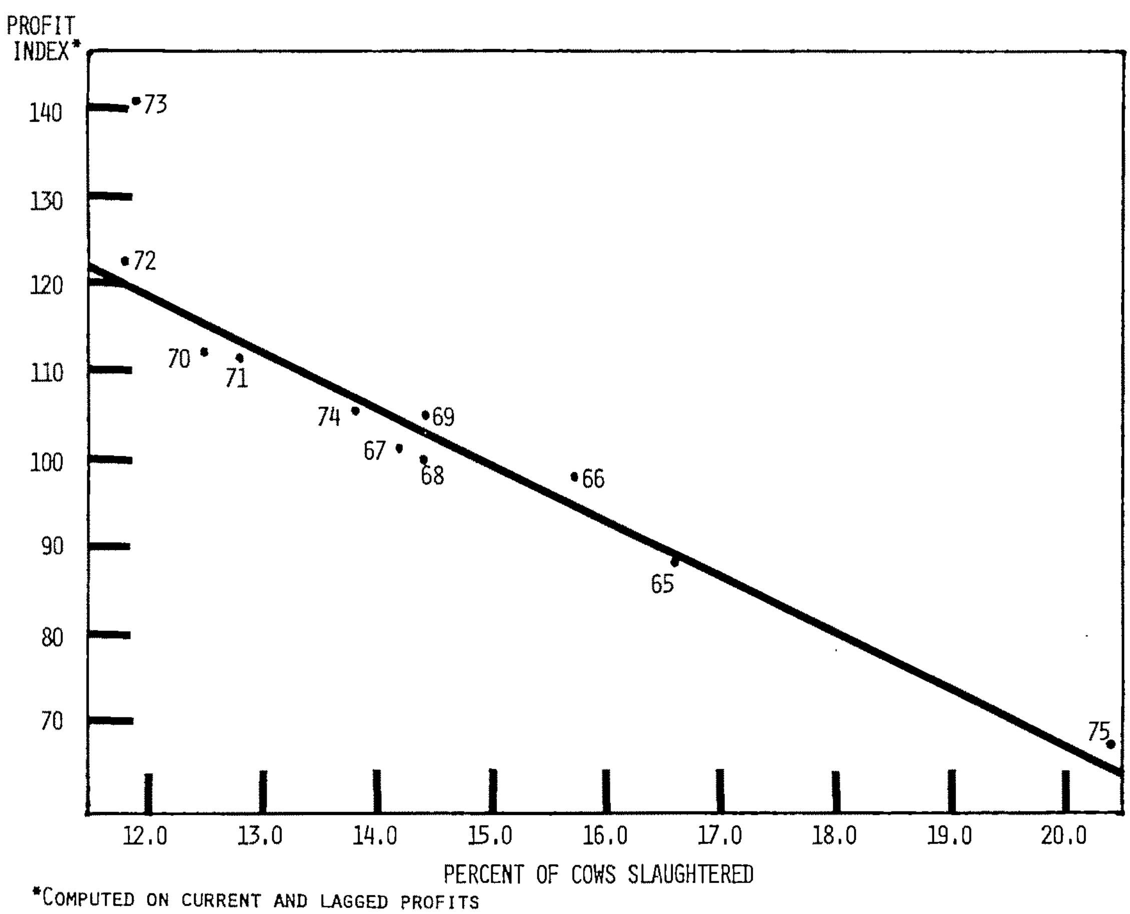

Figure 1. Percentage of 1 January cow slaughter and profit index, 1965–75

model. First, it reflects the decision-making process of the industry. The investment recovery in cow-calf operations is over an extended period. Therefore, the decision to keep or retain cows is a function of not only current profits but also of those that were accumulated in previous years.[1] Second, the model can be estimated by forecasting only one variable—this year's profitability. Third, the model is simple but yet describes the system. Finally, the model is easily understood and accepted by noneconomists.

The model uses profits, not prices. With the increases in levels and volatility of prices in the past several years, we have turned increasingly away from price variables to profit and dollar expenditure variables. For example, the dollars cattle feeders are willing and able to spend for feed grains is a function not so much of the price of the feed grain but of the dollars (profits) they have to spend for feed grain. Demand for a given item represents not only an ability but a willingness to pay for a given item. Ability is determined by the profits (income in case of the consumer) in hand or the credit available. The willingness is determined not only by current and expected profits (income) but by past profits (income).

From supply and expenditure levels, prices can be estimated. A theoretical problem with the approach is the variability of elasticities at different quantity levels. However, I have not found the theoretical problem here to be greater than the practical success resulting from an adequate description of the system. A real challenge to the profession is to determine the proper theoretical and practical basis for analyzing market forces and outcomes in the food industry.

Not only have many of the fundamentals of the cash markets eluded us but so also have those of the futures markets. The trading of nonstorable commodities caught the profession completely by surprise, and to date I have yet to see an acceptable theoretical or practical analysis of the live cattle or live hog futures markets. Neither have I seen any research designed to improve the management of converting margins through the simultaneous use of live cattle, feeder cattle, soybean meal, and corn futures. Logically, these four futures markets used properly would be a vehicle through which the cattle industry could transfer market risk to speculators. I suspect that part of the reason for lack of work in this area stems from the complexity of managing the four price bases involved and that many do not understand the nature of or function of a basis.[2]

In a talk to a seminar on futures markets sponsored by the Chicago Board of Trade, Amstutz said, "It has become increasingly clear to me over the past year that many, too many, do not understand basis. Understanding basis is fundamental to understanding futures and hedging. Your acceptance of this axiom should provide ample incentive to understand work in this area" (*Milling and Baking News*, pp. 35–36). In teaching of futures markets courses, we have traditionally taught the mechanics of transferring risk by hedging where hedging is defined as the sale (purchase) of a cash position offset by the purchase (sale) of a futures position. The risk involved in the ownership or the sale of the basis has been ignored. As all who have had basis positions know, there is risk in a basis position, and it must be managed just as the risk involved in a futures or a cash position.

With increasing price volatility, with an increasing need to manage risk, with new futures markets offering additional market alternatives, and with important rules governing commodity marketing trading being made by a new regulatory agency, the need and the professional incentive should exist to improve and intensify our research and education in understanding the function and mechanics of futures trading. Outside of a few people, such as Roger Gray, our profession has neglected a research area that has the potential for a large payoff.

In his comments, Amstutz stated, "I am totally unconcerned about the possible demise of the futures industry as a result in a 'breakthrough' in accurate, reliable, quantitative forecasting techniques" (*Milling and Baking News*, pp. 35–36). While I agree with a literal interpretation of this statement, realistic quantitative models are a useful vehicle for improving decision making. Our challenge is to spend more time in understanding market systems and less in developing more complex and sophisticated quantitative models.

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[1] Additions to or liquidation of the cow herd is also a function of expected profits. With no explicit "expectations" variable in the model, the implicit assumption is that "expectations" are also a function of current and lagged profitability.

[2] Basis is defined as the difference between cash and futures price. In addition, there are geographical bases (price differences among geographical areas) that must be managed.

Policy

Of all the disappointments many of us have had with respect to our profession during the past five years, none has been greater than the lack of evaluation of key economic policy decisions. The response of the profession was silence during the many market interventions of recent years, and our analyses have been based on the premise that the price volatility during this period was due to market forces alone. However, in addition to an examination of policy options for unstable prices, we need an analysis of policy as a source of price instability.

It would be easy to dismiss the price controls that were imposed as a one-time phenomenon that is unlikely to recur. However, the sensitivity of consumers and political leaders to inflation suggests that we cannot summarily dismiss them as a one-time phenomenon, and neither does the fact that export controls have been applied and taken off again several times since price controls were first applied. Therefore, a key issue is an assessment of the costs of the distortions caused by such market interventions. We need, for example, an assessment of the costs to consumers and livestock producers of our market intervention. Perhaps, more importantly, we should have an analysis of how the need or apparent need for such interventions can be avoided. Finally, we need to communicate effectively the results to key policy makers.

While this paper is not the place for such an analysis, let me examine one example of such costs. Marketing patterns of the beef industry were severely disrupted by the price controls of 1973. During controls, cattle were inventoried in feedlots and on ranches. Then, when price controls were removed, beef came to the market at rates faster than the market could absorb. Returns to cattle feeders plummeted. So, in turn, did the feedlot demand for feed grains and feeder cattle. The result was severe losses on the part of cattle feeders and cow-calf operators.

Hasbargen and Egertson recently published estimates that the losses over feed costs for cattle feeding and cow herds were \$21.16 per hundredweight and \$139 per head, respectively, in 1974 (p. 5). This compares with losses of \$6.50 per hundredweight and \$39 per head, respectively, in 1953. Taking the difference in losses between the two periods and using the number of fed cattle marketings in 1974 and the 1 January 1974 cow inventory results in a loss of over \$7 billion to the cattle industry that, in my opinion, can be attributed to the effects of economic policy.[3] The consequences of this are predictable—the largest liquidation of the cow herd since the 1930s. This effectively reduces our ability to produce beef.

The net result of the price controls was sharply higher prices in the short run, abnormally high losses for beef producers in the intermediate period, and higher beef prices for the consumer in the long run. The beef industry is not an isolated case. There has been variability in returns to pork and poultry producers during this same period. Subsequent to the price controls, the variability of livestock producers' cost and returns as well as the returns to grain producers have been exaggerated by the on-again–off-again export controls.

My point is this: economic policy in recent years has been a source of instability and costs and, consequently, has contributed to rather than reduced inflation. As Bottum pointed out, "if there is more than one choice, and there usually is, the procedure is to identify and delineate the problem, develop possible solutions, set forth the consequences of each solution and make the decision" (p. 765). Agricultural economists have not only overlooked part of the problem—economic policy as a source of instability—but have and still are failing to analyze and set forth the consequences of alternative solutions. Price stability will remain an objective of those in public decision-making positions, if not among economists. However, with an ever-increasing demand for food and an ever-increasing interdependence in the world, it will remain an elusive objective. Therefore, it is our responsibility as economists to set forth the economic consequences of alternative solutions, particularly the artificial controls that create costly dislocations throughout the system.

Comments on Current Research

In summary, industry economists are not asking our profession to abandon rigorous,

[3] It can be argued that in 1973 returns to cattle feeders were higher than normal because of the artificially high prices during the

theoretical analyses. Analyses designed to provide a better theoretical understanding of our food industry and/or to provide better tools of measurement and analysis are needed. The concern is the energies expended on rigorous analyses of obsolete data or on problems that do not exist. Let me illustrate with the following "do" and "do not" examples.

Do provide an objective evaluation of the economic consequences of changes in beef grades. Do not provide an analysis of where new lamb slaughtering plants should be located.

Do give us an evaluation of central cutting and packaging of beef. Do not give us another study on the optimum location of cattle feeding.

Do give us an analysis of the nature and extent of shifts in demand for various products. Do not flood us with explanations of how coefficients vary from two-stage to three-stage least squares.

Do provide research that is current and useful in today's decisions. Do not provide an analysis of a decision we had to make yesterday and will not have to make tomorrow.

Do tackle key policy issues. Do not delay analyses until after the policy decisions have been made.

The responsibility for the gap that exists between the type of research that is being done and that we in industry would like is not entirely the responsibility of our colleagues in academia and government. Communication is a two-way street. The approach of using AAEA meetings as a once-a-year forum to vent industry's frustrations is not satisfactory. Our requirements and the contribution our academic and government colleagues can make are too great for a once-a-year exchange. Therefore, there are do's and do not's for those in industry also.

Do communicate problems immediately. Do not rely on the AAEA meetings as the only medium of communication.

Do take the initiative in establishing a meaningful dialogue with academic counterparts. Do not expect those in universities and government to understand our needs if we have not discussed our needs with them.

Do read the "rigorous" articles in the *Journal* and elsewhere with the thought of gaining new ideas or techniques that could be useful to you. Do not put the *Journal* aside because the articles do not provide specific answers that you have.

Do share new ideas or techniques with academic counterparts. Do not cloak your research in secrecy. In industry, implementation of an idea is as important as the idea itself.

"shortage." However, if one adjusted for this based on volume differences, the losses would still be massive.

Recommendations

While there are those of us in industry who, at times, threaten to abandon the AAEA, I think there are more positive approaches and recommend the following. First, since research efforts and funds flow to those areas that receive professional recognition, the AAEA should appoint a committee, including industry representatives, that would select for an award the article in the *Journal* or elsewhere that makes the most significant contribution to the industry decision-making process. This award would be in addition to the outstanding *Journal* article that is now made.

Second, the AAEA should set aside a section of the *Journal* for short, applied articles to be written by those in industry or in other decision-making roles. This would be a vehicle of communicating to the profession key areas of concern to decision makers. Of course, industry economists would have the responsibility of writing such articles.

Third, I would encourage academic institutions and government agencies to have industry participation in evaluating academic, professional, and research programs. This is done now by many business schools, and it is a prime reason for the success of masters of business administration in the corporate environment.

Finally, there should be AAEA-sponsored seminars in which there would be an industry-academic exchange of problems and methodology. The AAEA is rich in professional talent and technical expertise. The number one problem is identifying common problem areas and ordering priorities, which can be overcome only through effective communication. Hopefully, implementation of the above recommendations will provide a greater degree of continuity in the dialogue between the industry and academic economists in the AAEA. History has demonstrated that these once-a-year critiques are not satisfactory.

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Public Food Assistance Programs: Impacts and Social Policy Role (Daniel I. Padberg, University of Illinois, Chairman)

Effects of the U.S. Food Stamp and National School Lunch Programs, Fiscal Year 1974

Paul E. Nelson, Jr., and John Perrin

The depressed thirties brought forth side by side the paradox of food surpluses and obvious need. Federally sponsored food programs simultaneously were aimed at raising farm income and improving diets (Gold, Hoffman, and Waugh, p. 1; Southworth and Klayman, p. 1). These pre-World War II objectives are embodied in current legislation, although emphasis has shifted from farm income support toward improved diets.

From their beginning, economists have recognized that an injection of funds by means of food assistance programs yields a different pattern of resource allocation than an equal injection by other means. For example, an injection to provide food assistance results in a different allocation of resources than an equal injection to support national defense.

In 1961 federal assistance to the food stamp, food distribution, and school lunch programs amounted to $466.5 million.[1] For 1975 the preliminary estimate is $6,139.1 million (USDA 1976). The 1975 figure is a 13.2 multiple of the 1961 statistic.

Programs of such magnitude deserve quantitative as well as philosophic analysis. The focus of this paper is on the quantitative. Its purpose is to measure the economic effects of these programs in terms of net changes in business receipts, household income, jobs, and gross national product (GNP). The analysis is based upon the assumption that the funding for food bonus stamps and the cash contribution to the schools is paid for by a tax increase.[2] The taxpayers' disposable income and, hence, expenditures were reduced prior to making the income transfers to the recipients.

The results of the analysis of food stamps, assuming a transfer from taxpayers to food stamp households in the form of bonus stamps, are reported in net terms because both the output increases associated with the income transfer to the participant household sector and the decreases in output linked to the increased personal income taxation of the nonparticipant household sector have been taken into account. The results of the analysis of school lunches, when the transfer is assumed to be in the form of a cash contribution, are also in net terms; however, the increases in output are linked to the federal cash transfer to the schools and not to the participant household sector.

Business receipt changes are reported on a sector-by-sector basis. As anticipated, some sectors were better off with than without the programs. Conversely, others would have

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The reactors for this session were Loren Geistfeld of Purdue University, Stephen J. Hiemstra of the Food and Nutrition Service, U.S. Department of Agriculture, and Wendell Primas of Georgetown University.

Paul E. Nelson, Jr., is an agricultural economist with the Economic Research Service, U.S. Department of Agriculture, and John Perrin was with the Division of Coordination Planning, Office of the Governor, Austin, Texas.

The following colleagues made constructive suggestions at various stages of manuscript development: Tom Carlin, Clark Edwards, Gar Forsht, Alden C. Manchester, Masao Matsumoto, Bob Reese, Gerald Schluter, and Abner Womack. Herbert Grubb of the Water Development Board, Texas, and A. C. Hoffman in Bull Shoals, Alabama, were also very helpful.

[1] These figures exclude special supplements to women, infants, and children (WIC), institutional distribution, and school milk activities.

[2] Alternative assumptions that could have been adopted include (*a*) all federal contributions were funded by deficit financing or (*b*) the 1967 data already included the needed funds.

been better off if there had been no programs. Overall, the economy gained. Of course, consideration of such changes would be incomplete without some treatment of a possible "output illusion," which in turn is associated with the flexibility of supply. Such considerations are treated at the close of this paper.

Food Stamp Program

The input-output technique is particularly well suited for measuring changes in business receipts and household income, which are associated with variations in the final demand for each sector's goods and services.[3] Additional computations are required and were made to compute the changes in gross national product.

Table 1 presents the increased business receipts (output), household income, and gross national product generated during fiscal year

[3] The 1967 U.S. Department of Commerce input-output model was adopted and adjusted for our analytical purposes. Details of the adjustments and assumptions are presented in a technical appendix developed to support two more extensive reports (Nelson and Perrin 1976a, b, c). Single copies may be obtained from the author upon request.

Table 1. Net Economic Effects of a Transfer from Taxpayers to Food Stamp Household in the Form of Bonus Stamps, Fiscal Year 1974

Sector	Change in Jobs (number)	Change in Business Receipts (1,000 $)
Agriculture, forestry, and fisheries	32,453	407,715
Mining	−182	−8,435
Construction	−157	−5,317
Food manufacturing		
Meat and poultry products	4,057	287,555
Dairy products	1,877	102,655
Grain mill products	1,036	89,529
Bakery products	2,267	59,181
Canned and preserved foods	4,178	171,873
Other foods and beverages	1,477	98,127
Subtotal	14,892	808,920
Nonfood manufacturing		
Clothing	−4,448	−43,803
Other manufacturing	−7,666	−237,523
Subtotal	−12,114	−281,326
Local and suburban transportation	−285	−3,566
All other transportation	−177	−5,449
Communications	−662	−15,327
Gas, electric, water and sanitary utilities	0	−707
Wholesale trade	11,463	249,145
Retail trade	48,980	461,343
Finance, insurance, and real estate	−4,248	−211,480
Personal services	−6,832	−45,728
Physicians and dentists	−1,237	−36,498
Hospitals and laboratory services	−1,910	−15,037
Education (private)	−685	−23,856
School lunch	−21	—
Other sectors[a]	−2,717	−77,850
Total	76,561	1,196,547

Sector	Change in GNP (1,000 $)
Combined Household Sectors	
Bonus stamps received	2,718,000
Plus income from new jobs	10,750
Minus increase in savings and taxes	72,447
Equals change in consumption expenditures	2,656,303
Nonparticipant Household Sector	
Income from new jobs	281,683
Plus decrease in savings and taxes	208,780
Minus tax to fund stamps	2,718,000
Equals change in consumption expenditures	−2,227,537
Net change in combined sector consumption expenditures	428,766
Plus change in school lunch expenditures	−1,905
Equals change in gross national product	426,861

Note: The nonparticipant household sector was taxed $2,718 million to fund bonus stamps. The expenditure of the bonus stamps was treated as an increase in final demand of this amount. Meeting this increase in final demand required additional economic activity.
[a] Other sectors is an aggregate composed of direct and transferred imports; business travel, gifts; office supplies; federal, state, and local government enterprises; and other services.

1974 by the injection of $2,718 million of bonus stamp expenditures. Column 2 indicates the net impact of the food stamp program upon specified sectors of the economy. Column 3 reports the net impact upon household income along with the net addition to gross national product.

In interpreting these figures, it should be noted that 55% of the bonus stamp expenditures were assumed to be spent for food and 45% for nonfood items.[4] This assumption provides the basis for identifying the extent to which business receipts and household income increments are associated with a change in the expenditure pattern rather than to an increase in total final demand.

Business Receipts, Household Income, and GNP

Estimates for 1974 indicate that total business receipts, household income, and gross national product increased as a result of the food stamp program. Business receipts rose about $1.2 billion, net household sector income, $292.4 million, and gross national product, $427 million.

Table 1 also shows that while some sectors benefited, others were less fortunate. Food and food-related sectors were expected to benefit. In 1974 the income distribution of nonparticipant households was skewed heavily to the right—above $10,000. The income distribution for participant households was skewed to the left—below $5,000. This meant that the marginal propensity to consume was much higher for participant than for nonparticipant households. In addition, the regulations that required participants to buy stamps valid only for the purchase of foods led to increased food purchases and services related to food marketing.

The agriculture, forestry, and fisheries sector experienced increases in business receipts of $408 million; food manufacturing's business receipts were $809 million higher than if there had been no program. Corresponding increases in business receipts for the wholesale and retail trade sectors were approximately $249.1 and $461.3 million, respectively. Much of this gain was probably contributed by the food wholesale and retail trade sectors. The precise amount cannot be determined because the U.S. Department of Commerce 1967 model does not disaggregate its sectors to that level. (Complete data on the U.S. Department of Commerce 1967 model can be obtained only on tape from that department.)

Of the food manufacturing sectors, meat and poultry, canned and preserved foods, and dairy products gained more than did the grain mill and bakery products sectors. When the dairy products sector is combined with the meat and poultry products sector, these protein sectors accounted for 48.2% of the total increase in food manufacturing business receipts.

Other sectors were less fortunate. These sectors experienced decreases in output associated with the direct tax increase that outweighed the increase in output due to the indirect and induced effects stimulated by bonus stamp expenditures. Specifically, the nonfood manufacturing sectors' output was $281 million less than it would have been without the program. The output for services other than the wholesale and retail trades was $358 million less. Among the services, finance, insurance, and real estate had the greatest difference in size of output, which would have been maintained if there had been no program. Its output (business receipts) would have been greater by $211.5 million.

Numbers of Jobs

Increased business receipts (output) are also associated with an increase in the number of jobs needed to meet the increase in final demand. Thus, the figures reported in table 1 reflect the increase or decrease in the numbers of jobs by sector as a result of the food stamp program. The number of job changes reported for the entire economy represents the algebraic sum of the job numbers by which the sector totals increased or decreased as a result of the program.[5] For 1974 there were 76,561 more jobs with the program than there would have been without it.

[4] The food-nonfood distribution is based upon the Reese et al. report and discussions of the basic data on which it is based. Technically, even though each food stamp issued is spent for food, there is the possibility of substitution of nonfood for food purchases if prior to participation the household spent a higher proportion of its net income for food than the rules for participation required.

[5] The total number of job-holding people within each sector in 1967 was divided into the total business receipts (output) for each sector in 1967. This business receipts per employee ratio was the factor divided into the change in business receipts, sector by sector, to estimate changes in job numbers.

The agriculture, forestry, and fisheries; food manufacturing; and retail and wholesale trade sectors added new jobs, while in contrast mining, construction, service, and nonfood manufacturing sectors had fewer jobs than they would have had without the program. The former sectors added 107,788 more than they would have without the program, while the latter had 31,227 fewer jobs.

The National School Lunch Program

Federal contributions to the school lunch program are made both as cash and as commodities.

Business Receipts, Household Income, and GNP

The injection of the federal cash contribution into the U.S. economy occurs when schools use the contributed funds to purchase food and labor required by the program. Table 2 reports net changes in business receipts, household income, and gross national product resulting from the schools' receipt and expenditure of the income transfer. With the transfer, business receipts were $573 million more than without it. Household income was $378.6 million and gross national product $397. 5 million higher because of the program. Again, as expected, the sectors that benefited most were the food sectors and those providing them direct services, e.g., wholesale trade.

The increases in business receipts on the part of the meat, poultry, and dairy products sectors appear to reflect nutritional requirements built into the school lunch program. In 1974 the combined meat, poultry, and dairy products sectors had a business receipts increase of $392.8 million. The combined rise of these sectors represent 70.3% of the total increase in business receipts by the food manufacturing sectors. (The corresponding figure cited above for the food stamp program was 48.2%.) The business receipts in the canned and preserved foods and the wholesale trade sectors also increased substantially, by $100.6 million and $52.0 million, respectively.

In contrast, other sectors whose output was less with than without the federal cash contribution were retail trade; clothing and all other manufacturing; finance, insurance, and real estate; physicians and dentists; and hospitals and laboratory services. Of these, the sector that would have gained most without the contribution was the finance, insurance, and real estate sector, whose increase without the contribution would have been $134.1 million more.

Numbers of Jobs

Table 2 also presents the number of new jobs derived from the change in business receipts. On balance, the economy had 26,383 more jobs because there was a federal cash contribution to the schools. Again, sectors that had the greatest change in business receipts tended to experience the greatest change in job numbers. Agriculture, forestry, and fisheries reported job additions of 26,389 and food manufacturing sectors, 10,445. Of these, the meat and poultry sector contributed 1,942; dairy products, 4,665; and the canned and preserved foods sector, 2,447. Two other sectors that added many jobs were wholesale trade (2,392) and school lunch (11,806).

Some sectors had fewer jobs than if there had been no federal cash contribution. For example, schools buy mostly from manufacturers and wholesalers. Thus, the retail trade would have had 11,265 more jobs without a federal cash contribution. All nonfood manufacturing (including clothing) would have had 3,689 more jobs without the program. Such differences among sectors are part of the fabric of the economy. Very few, if any, actions can be taken that would result in every sector gaining equally.

Supply Flexibility and a Possible "Output Illusion"

Although input-output models are useful in studying changes in an economy, the input-output technique implicitly assumes perfect flexibility of supply; its measure of change in real additional final demand is accurate only to the extent that supply flexibility provides the required additional goods and services. To the extent supply did not have sufficient flexibility to furnish these added goods, the increase in output and gross national product would be illusory in the sense that these would be exaggerated by our figures.

There are two particular questions that must be examined: (*a*) to what extent was there supply flexibility in 1967, the year of the base model's technical coefficients; and (*b*) was

Table 2. Net Economic Effects of a Transfer from Taxpayers to Schools by Means of a Federal Cash Contribution, Fiscal Year 1974

Sector	Changes in Job (number)	Changes in Business Receipts (1,000 $)	Sector	Change in GNP (1,000 $)
Agriculture, forestry,				
and fisheries	26,389	331,535		
Mining	15	710		
Construction	269	9,126		
Food manufacturing			Combined Household Sectors	
Meat and poultry			Income from new jobs	378,648
products	1,942	137,662	Plus decrease in taxes	
Dairy products	4,665	255,161	and savings	28,002
Grain mill products	304	26,236	Minus tax increase to fund	
Bakery products	815	21,282	federal school contribution	1,085,000
Canned and			Equals change in	
preserved foods	2,447	100,649	consumption expenditures	−678,350
Other foods				
and beverages	272	18,084		
Subtotal	10,445	559,074		
Nonfood manufacturing				
Clothing	−2,744	−27,025		
Other manufacturing	−945	−29,270		
Subtotal	−3,689	−56,295		
Local and suburban				
transportation	−276	−3,453		
All other transportation	584	17,952	School Lunch Sector	
Communications	−372	−8,600	Change in school lunch expenditures	1,083,382
Gas, electric, water, and			Minus increase in	
sanitary utilities	56	3,618	factor payments[b]	7,498
Wholesale trade	2,392	51,994	Equals change in	
Retail trade	−11,265	−106,109	consumption expenditures	1,075,884
Finance, insurance, and				
real estate	−2,694	−134,115		
Personal services	−2,648	−17,726		
Physicians and dentists	−613	−18,086		
Hospitals and				
laboratory services	−2,121	−16,703		
Education (private)	−262	−9,132		
School lunch	11,806	—	Net change in combined	
Other sectors[a]	−1,633	−30,596	sector consumption expenditures	
Total change in			Equals change in gross	
business receipts	26,383	573,194	national product	397,534

Note: The nonparticipant household sector was taxed $1,085,000 to fund the federal contribution to schools. The schools' expenditure of the cash contribution was treated as an increase in final demand of this amount. Meeting this increase in final demand required additional economic activity. This increased activity resulted in a contribution to gross national product of $397,534,000.

[a] Other sectors is an aggregate composed of direct and transferred imports; business travel, gifts; office supplies; federal, state, and local government enterprises; and other services.

[b] In this sector, it is composed primarily of depreciation of school lunch equipment.

there sufficient supply flexibility in 1974 to meet the increased final demand generated by the income transfers? The flexibility in some of the major sectors is discussed below.

Base Model Year—1967

Farm products supply. Cropland acreages harvested provides an indication of supply flexibility, including the impact of weather.[6] The acreage harvested in 1949 was an historic high. If these 352 million harvested acres are treated as representing a realistic capacity, the acres harvested in 1967 were equivalent to 85.5% of capacity (USDA 1975, p. 8). The historic high for livestock production was in 1973. In terms of units of livestock (animal equivalent basis) in 1967, the farm sector produced at 91.8% capacity (Allen and Devers, p. 6).

Manufacturing sector supply. At the manufacturing level the Bureau of Economic Analysis,

[6] Between 1964 and 1969, total land in farms declined from 1,110 million to 1,064 million acres or by 4.1% (USDA 1976a, p. 420).

U.S. Department of Commerce, reports two manufacturing capacity figures (Hertzberg et al., pp. 48–49). The first measures the respondents' concept of a maximum practical capacity. The second reports what the respondents believe to be the capacity level that would maximize their company's profits or other objectives.

If the actual rate is greater than the preferred, overutilization is implied. If the inverse pertains, undercapacity is assumed. For all manufacturing sectors, the 1967 actual capacity utilization rate was 84.0. Food, including beverages, was 79.5. The corresponding figures for the preferred rates of capacity utilization were 94.0 for all manufacturing and 90.0 for food.

Wholesale and retail trade sector supply flexibility. Corresponding estimates of capacity utilization are not available for these sectors. Retail stores have increased both square footages of sales space and the hours that stores remain open. The wholesale trade sector has modernized storage facilities, including computerization of order handling and mecnanization and containerization for storage and delivery.

The comparison of the increase in final demand for the retail and wholesale sectors generated by these two food assistance programs with the total business receipts for merchant wholesalers and retailers provides an indication of these sectors' capability to handle such added final demand without further expansion of their facilities and staff. The program-related increase in final demand amounted to 0.6% of 1967 total retail business receipts, and 0.9% for the receipts for the merchant wholesale sector.

1974 Comparison

Using the same measures for comparison for 1974 yielded a farm products index of 0.923 for crop land harvested (USDA 1975, p. 8) and 0.988 for animal units of livestock. This latter figure was down slightly from 1973, which equaled 100.0 (Allen and Devers, p. 6). The maximum practical capacity ratio for all manufacturing sectors was 82.5 and for food, including beverages, 79.8 (U.S. Dep. Commerce, p. 18). Thus, the companies were operating at less than their preferred capacity. The retail sector's increase in final demand generated by the food programs amounted to 0.3% of total 1974 retail business receipts. The corresponding figure for the 1974 merchant wholesale sector was 0.4%.

Summary

This evidence implies there was sufficient supply flexibility to meet the increase in final demand created by these programs. The increase in final demand may be considered "real" rather than illusory. The program's impact upon patterns of resource allocation is of sufficient magnitude to merit particular consideration in policy deliberations respecting food assistance and publicly sponsored income transfers.

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Administrative Aspects of Food Programs as Renewable Resources

Rodney E. Leonard

The topic of this paper is administrative aspects of food programs, particularly the stamp program. It is not viewed as an invitation to say how the job could be done better, although that was a temptation. Nor is the topic seen as an opportunity to castigate Ed Hekman and his minions, even though I would do so with relish.

Instead, the purpose is to describe an administrative concept for the food stamp program (and other food assistance programs) as an integral part of a consumer food policy. I will explore some of the philosophical concepts that guide food programs, discuss some of the techniques for monitoring and evaluating public service programs, and suggest an approach to administering public services that is a little different from that now practiced by the U. S. Department of Agriculture. In short, I want to discuss program philosophy as it relates to monitoring and evaluation within the context of public service management, all to achieve sound program administration.

The food programs seem to be caught today in the web of conflicting policies—policies in addition to those surrounding the debate over categorical aid versus income maintenance. On the one hand, an imperial presidency and an imperial Congress created the food stamp program as the magnificent gesture of an enlightened elite. Benefits are provided for the poor, who abuse the program or show it disrespect only at the peril of their class. For example, an administration that could, with the stroke of the proverbial pen, cause 10 million people to suffer a diet less adequate today than yesterday, is simply an enlightened despot dressed up in democracy's cloak. Yet, it nearly happened, and only a lawsuit stood in the way. A Congress that could propose a set of changes that would do much the same thing is just a crowd of Lady Bountifuls arguing that the Thanksgiving package is much too good for the poor folks.

On the other hand, there are nearly 32 million Americans for whom the lack of an adequate income gets translated into an inadequate diet, which inevitably leads to poor nutrition, poorer health, and all the related problems. They are citizens who live in communities that have begun to employ various federal programs to enable the community to better serve its residents. The food stamp program is one of those programs. It is a community service.

But food programs are more than a community service. They are a renewable resource. They are an act of God, as much as the flow of the river, the tree growing on the hill, or the birth of new life. They differ in that they are the result of an intellectual, or human process, while the others spring from a biological process. As a renewable resource, these programs have meaning only in their use, in the capacity to contribute to the quality of life for the individual in the community. The value of the program exists in its application, not its creation.

If the food stamp program is a renewable resource, then the administrative focus of the executive agency changes drastically. The function of administration within the imperial form is protective not only of the program but also of the virtue and reputation of the executive and legislative branches. Criticism of abuses and arguments over the ethics of using public funds to reduce hunger are implicit threats to these branches. An effective bureaucrat, in this context, is one who knows how best to keep the congressional committee and the White House happy, or at least to keep discontent at these levels at a minimum. The crucial point is that the administrative focus is on those who have an indirect interest in the program. Responses to these interests tend to cause administrative forms that hinder

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or restrict access to the program, a condition more harmful to the innocent user than to the program critics.

As a renewable community resource, the food stamp program requires a much different administrative process. The program administrator and staff are responsible to prevent or eliminate barriers to the program and to insure access by the community and its citizens. The administrator and the program staff perform a service function rather than act as guardians of the imperial dignity.

The legislative function, as a footnote observation, also shifts from a policing function to an evaluative role. The Congress would tend to assess the food stamp program in relation to a legislative emphasis on how best to insure the community is able to respond to the needs of all its citizens.

A crucial area for administration of a renewable resource program is the relationship between the federal, state, and local governments. Currently, administration tends to be a process for limiting responsibility rather than insuring performance. The general criticism of public service programs is not that they are unnecessary but they are unavailable or inadequate. (More is being heard lately about limited resources, but that is an issue of choices rather than limits.)

An imperial administration emphasizes the need to protect one's rear instead of securing performance. If a program is authorized and funded but does not reach many or most of those it is intended to serve, an imperial administrator will try to avoid blame or criticism or to structure his or her role to minimize responsibility. For example, it has become clear over the last ten years that an essential function of program operation is to identify, locate, and contact individuals eligible for food stamps, to explain the program and the process for establishing eligibility, and to assist those who need help in finding their way through this bureaucratic maze to obtain food stamps.

Outreach is a primary administrative responsibility for public service delivery, required by law since 1971. The federal courts have ruled that service programs without an outreach component are incomplete. The USDA only requires that state governments submit a plan as to how they would conduct outreach. With minor changes, most of these plans were approved; without great exception, none would provide the intensive outreach that is essential. It took a federal court order to require both the USDA and the state agencies to junk their "no-action" plans and to begin planning a process to insure performance. What the USDA was willing to accept was to be able to say, if criticized, is: the states had responsibility for planning outreach and did not do what they said they were planning to do.

A plan is an agreement to perform and not a treaty to limit responsibility. A federal-state food stamp plan should specify where outreach is most needed, state the number of individuals who will be contacted through an outreach program, include a timetable of program milestones that should be met, describe the staffing requirements (including job descriptions), state the supervisory relationships (including in the milestones the number and frequency of program performance reviews), and list the cost of outreach projects by communities.

The federal role in a renewable resource program is to assist states and local communities in developing operational plans for service delivery, to help in the development and training of competent staff, to support and encourage community participation in the development of the plans, to monitor the implementation of the plan and the operation of the program, and to provide support and technical resources to help solve the problems identified through the monitoring and evaluation process. The federal government, in addition, must act decisively to halt fraud and other criminal actions in relation to the program and to maintain federal standards where state or local authority chose to act contrary to the law.

Federal administration should emphasize these program administrative skills: planning, communications, monitoring, evaluation, community organizing, training, technical assistance, as well as regulation development, rule making, record keeping, public relations, personnel management, and financial management. Federally sponsored training should be provided on a regular and continuing basis, and employment and promotion should be based on participation in the training.

The administrative focus should view the food stamp program not as a service flowing from the office of the president or a congressperson but as a service flowing to the individual as a community resident. In the de-

velopment of program rules and procedures, a primary concern should be to assess the impact of a proposed rule or regulation on program access. If the impact analysis shows the likely result is to create a barrier to participation, then some other procedure to serve administrative needs should be found.

Similarly, the administrative view of evaluation should be as a process to identify areas where federal assistance is needed and can be offered. As program evaluation is often practiced currently, there is a tendency for evaluators to look upon themselves as investigators, cops in plain clothes. Even if an evaluator thinks otherwise, experience has taught state and local program staff to look upon them as someone whose visit always is followed by trouble. Evaluation is one step in the process of helping improve performance, not in assessing whom to punish.

Evaluation should be carried out under explicit conditions. Everyone should know what practices and activities are being evaluated and why. This is one of the basic arguments for as specific a state or community plan as possible. If a plan is viable, then the evaluation should identify problem areas and probable causes that can be corrected.

In a program as large (nearly 18 million participants) and as extensive (every county in the United States and Puerto Rico) as food stamps, a major and continuing problem is fraud and errors. Both tend to be lumped together in the public eye as losses of public funds due to dishonesty, deceit, and other skulduggery. There is probably some virtue to the generalization.

But the monitoring and the response to problems that surface in the evaluation are different for fraud than for error. Fraud or dishonesty can be practiced by everyone—by the food stamp staff, by the business community involved in handling stamps, and by the participant. Suppressing dishonesty requires both an acceptance by the community of the food stamp program (and thus peer pressure to stop abuses) as well as the normal skills of investigation, detection, and arrest. Fraud is a major problem in every public service program, and the effort put forth by the government to check and control fraud needs to be thorough and complete. It is one of those situations where public assurance of action is placed on the substance of procedure rather than on the reports of its effectiveness. In the case of food stamps, for example, this would involve a five-stage federal effort to build the capacity of state agencies to deal with fraud.

(*a*) Evaluate the current state agency efforts through a literature search, and select five or more of the most effective state agencies for further study.

(*b*) Develop surveys that will evaluate legislative and administrative practices on essential elements of fraud control and handling, such as staffing, procedures for investigating, administering, and restitution and for prosecution referral.

(*c*) Collect, using the survey instruments, information from states' public assistance agencies, fraud investigative units, and the state and district attorney's offices.

(*d*) Compile the information into a "Best Practices Report" for each state covering the administrative and policy relationships that have led to an efficient means of detecting, investigating, and prosecuting food stamp fraud cases. These reports could be used in information programs and in training and technical assistance efforts provided by the federal government to state and community agencies.

(*e*) Develop, as a major product of the analysis of survey materials, a "Federal Options Paper." This would identify possible changes in policy, in administrative procedures, and in organization practices such as the system of accountability for investigating and reporting fraud, administrative and legal sanctions, procedures for handling those who defraud the program, range of corrective actions available, and legal remedies.

The actual distinction between error and fraud, while important in efforts to investigate and prosecute recipient fraud, does not significantly change the methods for error detection. In other words, most corrective actions taken in the determination and retermination processes will reduce both error and fraud. The essential function, once an error is determined, is to distinguish if it is a fraud or an error and to take an appropriate action.

Errors are predominantly a staff problem, although participant error also exists, and work both ways. Some cause the federal government to pay more in benefits than an individual is entitled to receive; some cause individuals to receive less than they should. In one case the public is defrauded; in the other the individual citizen is defrauded. However,

where the problem is human error, program administration will have to rely primarily on administrative, as opposed to judicial, procedures to minimize the problem. The task is to improve staff skills to overcome institutional weaknesses.

This defines more explicitly the administrative or managerial problem. It is possible to educate individuals to fill certain staff functions, but education in no way trains the individual for the institutional role and the institutional problems. The food stamp program is an institutional mechanism, operating within the federal system of government to insure the delivery of a renewable resource to individual citizens in the community where they and their families reside.

The administrative resource needed to overcome institutional weaknesses, such as staff or other human error, is training and technical assistance (TTA). TTA is a crucial instrument for building institutional capability. Through TTA it is not only possible to communicate the necessary skills to overcome an operational problem but also to explain the various individual functions and skills within the context of the program and its purposes. It relates—or should relate—what one person at the federal level is doing to what another at the state level is doing, and what both are doing in relation to the certification worker in the community program. Training and technical assistance is not a function that universities or colleges perform well or easily, although it is a service in which they profess competency. Although there are several reasons, the basic problem is that TTA is ineffective in an academic form. A person can learn the principles of good program management, for example, but the institutional problems that occur because of bad management will go unchecked unless principles are demonstrated and used as organizationally specific practices applied to organizational or program goals.

The basic value of TTA is in its application as a problem-solving technique by program managers and administrators within a uniform program standard; that is, TTA is a continuous and on-going activity to be used by administrators to communicate the value and purpose of the program, an awareness of problems, and their desire and intent to solve them. One of the spin-off values of TTA is to provide a basis for evaluating individual performances and for determining the allocation of rewards, such as in-grade pay increases and promotions. There are other virtues and some real potential problems with TTA as an institutional support mechanism, but that is the topic for another paper. My purpose here was to present a new administrative concept, to discuss how it might affect the conventional administrative approach, and to examine some of its features.

Food stamps are a renewable resource program, serving a consumer function, and must be viewed as a resource coming toward the individual, not away from the producer, or, in this instance, the imperial form of government. The imperial presidency ended in 1968, although the ghost did not depart until August 1974 after all the president's men had gone. The imperial bureaucracy is still with us, although that is about to change. When it does, there will not be less government; the imperial presidency is gone, but the executive and its institution continues. The bureaucracy will remain as will its purpose, but its function will be different as will its perception of the bureaucracy. There will be a new procedural emphasis on planning, on citizen participation, on monitoring and evaluation, on training and technical assistance as part of the substance of service delivery, and, one can hope, on the quality of life for the consumer, poor and rich.

Social Policy Role of Food Assistance Programs

James R. Storey

In fiscal year 1977, the federal government will spend $9.2 billion on food stamps and child nutrition programs. These benefits represent the bulk of the government's direct efforts to improve nutrition. Viewed more generally, these programs are only a few among many federal mechanisms for transferring income from one group of people to another to improve the recipients' financial status. Food programs account for only 5% of all such transfer payments, but food assistance constitutes a higher proportion of benefits (24%) directed to low-income groups. Thus, food assistance is a very important element in federal income support.

There have been a number of studies of the impact of food stamps and the school lunch program on the nutritional well-being of program participants (USDA). Viewed as a body of knowledge, these studies tell a nonexpert decision maker several things: (*a*) the programs do increase food consumption; (*b*) although the evidence is less convincing, there does seem to be nutritional improvement as well; (*c*) to be more efficient in achieving these two goals, food programs would have to be more carefully targeted, both in people served and in food and nutritional services delivered; and (*d*) nonfood income transfer programs also increase food consumption, although probably to a lesser degree than do food programs.

However, it is necessary that not only food programs but other types of aid as well be related to other social goals in order to understand in broader perspective why we are transferring $187.9 billion of American tax dollars through the various income transfer programs and what it is that we are accomplishing with these sizable expenditures.

Of course, the narrower goal of good nutrition underlies many other broader social goals such as longevity, equal opportunity for education and work, and freedom from disease. Given the limits on our knowledge on achieving all these objectives and the limited funds with which to pursue them, there will always be a struggle over the emphasis any particular goal receives.

Taking the three largest food programs as examples, each seems to typify a different way of pursuing broader social goals through programs that transfer income by subsidizing food purchasing power. For instance, the special supplements for women, infants, and children (the WIC program) carefully target a relatively small amount of money ($250 million) to purchase high-nutrition foodstuffs for people that clearly have special nutritional needs, thereby emphasizing a nutritional goal over all other possible results and constituting an important effort to improve maternal and child health. The school lunch program, which spends $2.4 billion a year, serves more of an educational purpose, presumably helping poor children do better in school by providing them with free lunches and freeing up state educational funds for other more directly educational purposes by subsidizing school cafeteria operation. The food stamp program, with fiscal 1977 outlays estimated at $6.2 billion, has its nutritional goals so diluted by the broader population served and the total reliance on consumer choice that it relates much more to the purposes of general income maintenance and to programs such as aid to families with dependent children (AFDC) and supplemental security income (SSI) than to a nutrition program such as WIC. Given the importance of food stamps as a welfare program and the likelihood that the income maintenance policy debate will intensify next year, it is the linkage between food programs and income transfer policy that this paper addresses. The health and educational aspects of food assistance cannot be treated adequately in a paper of this length.

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The views expressed are the author's and do not necessarily reflect the view of the Budget Committee or any member thereof.

Food stamps are an integral part of the larger income transfer system. As the only public program to serve all categories of low-income people in all parts of the country, food stamp recipients also benefit from many other programs. A 1974 survey found that 60% of food stamp households also received cash aid, 30% participated in medicaid, and 36% received social security checks (U.S. Congress). This concurrent effect of numerous programs on a group of people means that social goals and policy issues cannot be viewed in isolation for food stamps or any other program but must be considered for the system as a whole.

What goals should income transfer payments serve? There are three basic goals that most people would agree stand above all others: all Americans (*a*) should have incomes sufficient to live at a level considered adequate by society, (*b*) should have incomes that are judged equitable with respect to past or present efforts at self-help and in light of any particular circumstances requiring extraordinary remedies, and (*c*) should receive those incomes in a manner least disruptive to the working of the private economy. These ideals form a good framework for evaluating income transfer policy.

Income Transfers and the Federal Budget

Importance of Income Transfers to the Budget

Income transfer policy is a major determinant of our fiscal policy. Income transfer payments to increase the real income of beneficiary groups through cash payments and subsidized health care, food, and shelter will account for $187.9 billion, or 45%, of the $413 billion outlay total in the 1977 Congressional Budget Resolution.[1] This sector of the budget is not only the largest but also the most rapidly growing sector and the most difficult to affect in terms of short-run budget outlays.

[1] The programs considered in this paper are those in which the government provides financial benefits rather than services to recipients. Excluded are benefits tied to investment in human capital, such as GI bill benefits. Taking a broader view, one could view such programs as income transfer programs. Also excluded are $36.1 billion in tax expenditures that serve the same purpose as the expenditure programs discussed in this paper. For example, double exemptions for the aged and blind and the exclusion of transfer payments from taxable income are tax measures that transfer income to selected categories of individuals.

Types of Income Transfer Programs

There are three ways in which it is useful to classify income transfer programs: (*a*) those that pay cash benefits to recipients and those that offer aid in the form of subsidized food, medical care, or rent, (*b*) those that are contributory or self-financing and those that are not, and (*c*) those that base benefits explicitly on need and those that do not.

The bulk of income transfers (71%) are funded by earmarked taxes (table 1). Social security and medicare alone account for 56%. Cash benefits based on need make up only 9% of federal income transfers, a proportion now exceeded by noncash welfare programs (12%) and nonwelfare cash benefits (9%). The relative decline in importance of cash welfare benefits is recent, resulting from the rapid growth of noncash aid (e.g., food stamps, medicaid) and nonwelfare programs (e.g., coal miners' benefits, military retirement, temporary unemployment benefits).

Trends in Growth of Income Transfers

Over the last twenty years, income transfer payments have quadrupled on a constant dollar basis. Based on the current services budget the president submitted to Congress last year, these payments will account for $22 billion of the $46 billion of "automatic" growth in the federal budget from 1976 to 1977. Thus, concern has arisen over what the future growth pattern may be.

The Congressional Budget Office (CBO) projected benefits under current law to the year 2000. These projections show that payments in 2000 will be two-and-one-half times the present level in constant dollars (U.S. Congressional Budget Office). This growth will result simply from growing beneficiary populations, the impact of real wage growth on benefits, and the indexing of benefits to inflation. But as a share of the gross national product (GNP), the projections show the present 9.3% of GNP for income transfers staying about the same. If provisions in current law that overcompensate for inflation are corrected, only two programs would experience significant growth in share of GNP: medicare, due to expected cost inflation, and federal employee retirement, because of the many employees hired in the 1940s, 1950s, and 1960s who will be retiring and the growth in pay over those decades.

Table 1. Income Transfer Budget Outlays and Beneficiaries by Program Type, Fiscal Year 1977

Income Transfer Programs	Average No. of Beneficiaries (millions)	Federal Benefit Outlays (billion $)	Outlays as Percentage of Total
Total, income transfer programs		187.9	100.0
Cash benefit programs		144.3	76.8
Contributory		111.8	59.5
Social Security (OASDI)	33.3	83.4	44.4
Civil Service retirement	1.5[a]	10.1	5.4
Unemployment compensation	9.2	14.5	7.7
Noncontributory		16.3	8.7
Military retirement	1.2	8.5	4.5
VA disability compensation	2.6	5.6	3.0
Noncontributory (need-based)		16.2	8.6
AFDC	11.3	6.8	3.6
SSI	4.6	6.0	3.2
VA pensions	2.2	3.2	1.7
Noncash benefit programs		43.6	23.2
Contributory (Medicare)	24.9	21.6	11.5
Noncontributory (need-based)		22.0	11.7
Medicaid	23.6	9.6	5.1
Food stamps	18.9	6.2	3.3
Child nutrition programs	26.3	3.0	1.6
Subsidized housing programs	7.7	3.2	1.7

Sources: U.S. Congressional Budget Office 1976, U.S. Office of Management Budget.
Note: Detail shown as non-add entries because the smaller programs are not shown in this table.
[a] End of year number.

Of course, further growth over and above the CBO's current law projections may occur through new legislation, but program expansion is unlikely to match the pace of the past twenty years, which saw many landmark changes, such as the establishment of new programs (medicaid, medicare, food stamps, coal miners' benefits, mortgage subsidies, liberalization of social security coverage and benefit rules, automatic cost-of-living adjustments, and greater sharing in state welfare payments). But should the past growth rate be duplicated over the next twenty-five years, transfer payments in the year 2000 would be more than three times the level projected for current law.

There are numerous pressure points for greater spending on income transfers. Despite the rapid growth in payments, the bottom 20% of American households still receive only 8% of total personal income, about the same share as twenty years ago. A large poverty population in absolute terms still remains as well. To eliminate poverty through transfers would require additional payments of at least $8 billion and probably much more to minimize adverse effects of a poverty-level income guarantee on work incentives.

Further pressures arise from demands to rectify inequities in the hodgepodge of programs. For example, the AFDC payment level in Wisconsin is six times that in Mississippi. AFDC and medicaid are available to low-income female-headed families in all states, to intact families headed by unemployed fathers in about half the states, but to intact families with fathers working full-time in no state. Social security does not benefit working wives upon retirement at a level commensurate with their contributions, since wives receive 50% of their husbands' benefits without ever working for wages. To remedy inequities costs money, since the payments to persons benefiting from reforms usually outweigh reductions in the benefits of other recipients.

Controllability of Income Transfers

An important fiscal characteristic of these programs is their uncontrollable nature. Given the legal, moral, and political necessity of making payments to which people are entitled

under law, initiatives to curb normal growth, reduce expenditures, or reprogram spending can have relatively little impact in a period as short as the next budget year.[2] The traditional budgetary process has involved marginal changes in the budget base for the fiscal year that begins a few months after the preparation of the new budget. Given this amount of lead time, substantial discretionary changes in income transfer outlays are unlikely since most would require legislation, a lengthy process when controversial matters such as income redistribution are involved.

Even if legislation moves quickly, budgetary effects may be overshadowed by program responsiveness to inflation (83% of transfers are indexed for price increases), unemployment (a percentage point rise in unemployment adds about $3 billion to transfer payments), or the behavior of beneficiary groups, who may change their rates of retirement, childbearing, divorce, or school attendance. Such changes can offset the effects of policies aimed at budgetary change.

Control over spending is also hampered by difficulty in implementing administrative improvements. Probably several billion dollars of transfer payments are improperly made, mostly due to inadequate program administration.[3] Although this money could be saved, actually doing so is difficult. First, the offending administrative practices may be based on statutes or court decisions with remedies requiring new law. Second, administrative problems may result from inadequate staff, complex laws and regulations, poor coordination among multiple agencies, and lack of resources in the judicial system for prosecution of fraud. None of these factors is easily overcome in the short span of a year, and those improvements that are possible must be worked through enormous federal agencies or, with even more difficulty, through federal agencies that only regulate the administrative practices of fifty states and over 3,000 counties. Finally, benefit savings may be offset in whole or in part by increased administrative costs.

[2] The Congressional Budget Resolution for fiscal 1977 assumed legislative savings for income transfer programs of $1.4 billion, or less than 1% of total benefits. Only a small part of these savings (no more than $0.2 billion) will probably be realized.

[3] The actual net loss of benefits that results from overpayments, underpayments, and eligibility errors is not precisely known. This rough estimate is drawn from materials collected by the U.S. General Accounting Office for the Senate Budget Committee.

Taking a longer view, however, there are opportunities to curb growth in income transfer payments. For example, the CBO's projections to the year 2000 illustrate that $19 billion per year in 1975 dollars could be saved by eliminating automatic provisions that overcompensate for inflation. Finding ways to slow the rise in health care costs would save billions in outlays under medicare and medicaid. For example, if the rate of price increase that the CBO projections assumed was halved (from 10% to 5% yearly for hospital costs), expenditure savings would total $28 billion annually by 2000. However, to achieve such annual savings in the short run ($47 billion for the above examples) would require eliminating whole programs or substantially reducing social security benefits. Relatively small initiatives taken now could produce sizable shifts in program costs over the long run.

Effects of Income Transfers on the Income Distribution

Although total income transfers will average about $875 per capita this year, and despite the rapid growth in payments, there has been no major change in the distribution of income, and the nation still has a sizable poverty population. In part, this paradox results from the Bureau of Census's failure to count noncash transfers (e.g., food stamps, medicaid) in official statistics. But the data problem is only a partial answer, since noncash benefits are only 23% of total transfer payments.

The main reason for the ineffectiveness of transfers in redistributing income is the dominance of social insurance benefits over benefits strictly for the needy. Social insurance programs were designed to transfer income from wage earners to those no longer in the work force. Thus, the relative neutrality of these programs with respect to the income distribution comes as no surprise. Since social insurance programs such as social security account for 80% of all transfer payments, while cash welfare benefits are only 9% of the total, social insurance payments tend to dominate the overall results produced by the income transfer system.

The primary effect of welfare-type programs is to transfer income from higher- to lower-income classes with funds drawn from

the progressive federal income tax. But social insurance benefits are mainly transfers within the working class population, from current workers to former workers and their families. Furthermore, these transfers are financed by payroll taxes that are regressive in nature; i.e., they are relatively heavier for low-income workers than for others. All workers pay the same social security tax rate (5.85% on both employer and employee), but only the first $15,300 of annual earnings are taxed.

Reynolds and Smolensky have measured the change in posttax, posttransfer income shares from 1950 to 1970. Their study shows that the income share for the bottom 20% of the income distribution rose from 7.2% of all income in 1950 to 7.9% in 1970. Over that period, income transfer payments quadrupled in real value and rose from 3.7% to 8.6% of the GNP. The study shows that government activity did serve to reduce income inequality to a greater extent in 1970 than in 1950. The relative importance of transfers in reducing inequality tripled over that time period, while taxes became less progressive and play only a small role in equalizing income.

There are still 24.3 million Americans living in poverty (less than $5,500 for an urban family of four).[4] The number has declined from 28.5 million in 1966, but the decrease occurred during periods of economic growth. The number of poor people is actually about the same as in 1969, despite the rapid growth in transfer payments.

A book by Plotnick and Skidmore contains an analysis of the impact transfer payments have had on the extent of poverty. The number of households that would have been poor if no transfer income were available actually increased from 1965 to 1972 by 2 million to a total of 17.6 million. The income gap, the aggregate dollar value of income required to eliminate poverty, grew by $5 billion to $34.3 billion. The effect of transfer payments was to offset the potential growth in poverty, with posttransfer poor households remaining about the same in number (9.9 million in 1972). The posttransfer income gap declined from $13.8 billion to $12.5 billion. Over this period, the proportion of transfer payments received by pretransfer poor households that was not needed to remove them from poverty increased from 31% to 36%, and half of all transfer payments went to households that would not have been poor even without those payments. Thus, about two-thirds of transfer payments did not reduce the poverty income gap at all (the 50% that went to the nonpoor plus 36% of the 50% that went to poor households).

The impact of transfer payments on poverty differs greatly among demographic groups. In 1972, transfers removed 63% of otherwise poor households with aged heads from poverty, social security alone accounting for 51%. For nonaged households, only about one-fourth of pretransfer poor households were pushed out of poverty, with social security and public assistance playing comparable roles.

Plotnick and Skidmore indicate the estimated proportion of transfer payments going to pretransfer poor households. AFDC, SSI, medicaid, and food stamps are the more efficient programs in reaching the poor (over 75% of payments go to poor households). One welfare-type program, subsidizing housing, is no more poverty-effective than the social security program, which serves a much wider clientele, but still pays a little more than half its benefits to pretransfer poor households. Unemployment insurance, surprisingly, has the lowest proportion of payments going to such households (only 21%).

Criteria for Evaluating Policy Alternatives

Instead of forming a coordinated system to achieve well-defined goals, income transfer programs are an assortment of fragmented efforts that distribute income to a variety of persons for a variety of purposes, on conflicting terms, and with unforeseen effects. Two primary factors have inhibited a uniform system of equitable aid: a tradition of local responsibility for the needy and a habit of approaching social problems in isolation, developing new programs to attack newly perceived problems. Only with passage of the 1970 food stamp amendments and the enactment of SSI in 1972 did the federal government set national eligibility rules and benefit levels for welfare aid to groups other than veterans.

Our past practice of approaching problems in isolation has led to fragmented and inconsistent legislation and administration. Our income transfer programs are shaped by at least

[4] The number of poor people is an overstatement since noncash benefits such as food stamps are not included in the computation.

nineteen committees of Congress,[5] fifty state legislatures, six cabinet departments, three other federal agencies, fifty-four state-level welfare agencies and more than 1,500 county welfare departments, the U.S. Supreme Court, and many lesser courts.

Each congressional committee typically deals only with its own subject area, although changes in one benefit program, such as AFDC or social security, commonly affect another, such as food stamps or veterans' pensions. Because of the categorical nature of the "system" and the restricted viewpoints of agencies and congressional committees, attempts to remedy one problem may create another. For example, if the House Ways and Means Committee alters AFDC eligibility, this affects eligibility for food stamps (Agriculture Committee) and medicaid (Interstate and Foreign Commerce Committee) in ways these committees may not favor.

None of the committees has the duty to appraise the total effect of congressional decisions. As a result, for example, persons can be enrolled in several programs, the terms of which discourage work and provide income that far exceeds their earning potential, but no one committee can easily deal with such a cumulative result.

In considering income transfer policy alternatives, it is not the effect of each separate program but of the whole system as it applies to each eligible family or individual that is important to evaluate. Important criteria for such evaluation include the following.

(*a*) Equity—are all groups treated fairly based on a consistent set of principles? The groups excluded from AFDC and medicaid constitute 38% of the poor but receive only 13% of transfer payments. Benefits are lowest in the South and are lower nationally in areas that are poorer, more rural, or more black than average.

(*b*) Adequacy—are benefits at appropriate levels to achieve program objectives? Payments are often too low, e.g., $60 a month for a family of four on AFDC in Mississippi, but in urban states cumulative benefits often exceed the after-tax earnings of the average working woman.

(*c*) Incentives—does program design or operation encourage undesirable behavior by recipients? Combined benefit-loss rates allow a person on AFDC and food stamps to keep only 23¢ out of an extra dollar earned. Participation in other programs reduces work incentives further. AFDC and medicaid also discourage marriage for a woman with children due to exclusion of working males from eligibility.

(*d*) Administrative integrity—do program rules permit a reasonable level of enforcement and a high degree of accuracy in administrative actions? Errors in benefit determination run high, over 33% for AFDC, about 25% for SSI, and over 50% for food stamp recipients not on AFDC or SSI. Much of this error is linked to specific laws or regulations that are difficult to enforce.

(*e*) Federal-state-local fiscal relations—is financing equitable with respect to state and local fiscal efforts and with their need for federal funds? Problems clearly exist. For instance, New York City pays 25% of the cost of AFDC and medicaid, while most cities pay nothing. Lower federal matching rates for administrative costs than for benefit payments or provision of services offer states little financial incentive to strengthen program management.

Suggested Policy Directions for Food Programs

Given the enormous commitment of public funds to income transfers and the fact that many social objectives have yet to be reached, we seem to have entered an era in which restructuring the system will be considered more seriously than ever before. Adding to the urgency is the breakdown at the local office level in operating such programs as food stamps, medicaid, and SSI and the policy confusion in Washington in coping with a system legislated by nineteen congressional committees and administered by nine executive agencies. The interest in budgetary control and more efficient targeting of funds sparked by the congressional budget process also adds to the pressures for systematic reform. Such reform should include a restructuring of food assistance programs.

If Congress wants to devote more funds specifically to improvement of nutrition, the WIC type of program would seem to offer more payoff by carefully selecting a clientele in need of help and directly dispensing to them

[5] These committees include the Appropriations, Agriculture, Veterans', Post Office and Civil Service, Banking, and Armed Services Committees in both houses, plus the Senate Finance and Labor and Public Welfare Committees and the House Ways and Means, Education and Labor, and Interstate and Foreign Commerce Committees.

the kinds of food they require. If a more general approach is desired, perhaps greater efforts at nutrition education should be tried.

The food stamp program should be replaced by a federally administered cash payment system for income maintenance. It already comes closest to approximating the type of program that welfare reform advocates have considered preferable. By setting benefits at levels sufficient to replace food stamps, AFDC, and local general assistance, a more adequate and equitable program could be established that would also be easier to administer. It could be designed to reduce the incentives that now exist that are economically and socially disruptive, and the financial burden that states and localities now shoulder could be lessened.

Short of total welfare reform, enactment of food stamp reforms such as the Senate passed this year would help rectify the administrative problems besetting the program and achieve greater equity among the different groups of recipients. Elimination of the purchase requirement would be a further program reform that would bring additional relief to administrators and would bring in some of the neediest nonparticipants who cannot afford the prices now charged for the stamps. The school lunch program is enmeshed in school finance and should be discussed in that context, which is beyond the scope of this paper.

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Abstracts

Contributed Papers

Agricultural Finance (John Brake, Michigan State University, Chairman)

"New Equity: A Look at Texas Agricultural Limited Partnerships and the Investors Who Fund Them." Ted M. Abele, Raymond A. Dietrich, and Donald R. Levi (Texas A&M University).
Data drawn from certificates of limited partnership and two independent surveys relate the number, kind, and character of limited partnerships investing in Texas agriculture. Also set forth is a socioeconomic profile of limited partners investing in such funds as well as an overview of the investment objectives.

"Correspondent Banking in Agricultural Finance: An Analysis of Profit Requirements and Pricing Procedures." Peter J. Barry (Texas A&M University)
The principles of customer profitability analysis are applied to overline participation in farm loans by correspondent banks. A simulated borrowing situation is used to measure the level of participation and profit requirements on overline farm loans of a sample of correspondent banks with implications drawn for rural bank management.

"Impact of Capital Gains Taxation on Farm Organization: Implications for Meat Animals Production on Diversified Farms." Wesley N. Musser and Fred B. Saunders (University of Georgia) and Neil R. Martin, Jr. (CED-ERS-USDA, Athens, Georgia)
Differential income taxation of capital gains applied to components of enterprise net income for representative farm situations in Georgia resulted in increased hog production and a shift in production system. Maximum aftertax income objectives have larger impacts on farms with higher family incomes. Efficiency implications warrant further research.

"Farm Financial Management and Tax-Deferred Retirement Plans: Some Economic Aspects of Alternative Investments." Darrel L. Acker and Paul L. Wright (Ohio State University), Gerald A. Harrison (Purdue University), and Julian H. Atkinson (CIC-AID)
Many people may be misled by advertising on tax-deferred retirement plans. Comparisons of accumulated retirement benefits from alternative earnings and tax rates for both "tax-shelter" and no tax-shelter investments is wise financial management. Tax-deferred retirement plans should be integrated with the individual's estate management strategy.

"Explaining Farm Operators Debt: An Application of the Automatic Interaction Detector Technique." David A. Lins and Timothy R. Donaldson (University of Illinois)
The Automatic Interaction Detector technique is used to examine variations in farm operator debt. Results suggest that size and expenditure variables are the most important in explaining variations in the amount of farm operator debt. Geographic, demographic, and structural variables were found to be of less importance.

Energy and Environmental Issues Re Agriculture (James Wade, University of Arizona, Chairman)

"Impact of Crop Selection on the Costs of Wastewater Land Treatment." Edward B. Bradley (Pennsylvania State University)
Crop production can be an integral part of land treatment. Net total treatment costs are simulated for systems growing corn, alfalfa, and reed canary grass. Growing reed canary grass minimizes treatment costs, due to its longer irrigation season. Assuming an 85% capital subsidy, growing corn grain minimizes local costs.

"Regional Effects of Imposing Pollution Control Regulations on the Egg Producing Industry." Jawahar L. Kaul and P. Geoffrey Allen (University of Massachusetts)
A six-region econometric model of the U.S. egg producing industry combined with a modified transportation program generated the efficient production, consumption, and transshipment pattern. Production cost increases with pollution control of 5% and 10% were assumed to investigate impacts on net social costs and optimum pattern.

"Accounting for Tillage Equipment and Other Machinery in Energy Analysis." Otto C. Doering III, Timothy J. Considine, and Catherine E. Harling (Purdue University)
The energy value of different tillage equipment and farm machinery is presented in this paper based on industry sources. Discounting, scrappage, and utilization are discussed. Comparisons are made between the new disaggregated data and original attempts to determine farm machinery energy content based on the energy content of automobiles.

"Energy Scarcity and Nonpoint Source Pollution in Midwestern Agriculture." D. Lynn Forster and Norman Rask (Ohio State University)
Reduced tillage systems are primary methods of lessening erosion. This study investigates the impacts of energy prices on these systems. Results indicate that energy prices substantially affect corn

and soybean production costs; however, energy prices have little impact on the choice of tillage systems.

"Economic and Environmental Impacts of Energy Rationing in Agricultural Production." Dan Dvoskin and Earl O. Heady (Iowa State University)
The economic and environmental impacts of energy rationing are compared with high energy prices in agricultural production. Energy rationing leads to a much larger increase in commodity prices than high energy prices. Environmental impacts of the two policies are very similar. But regional production patterns change substantially between policies.

Forecasting and Projecting (David Dyer, Food and Nutrition Service, USDA, Chairman)

"Combining Linear Programming Results and Time Series Data for Prediction of Supply: Two Approaches." C. Richard Shumway and Hovav Talpaz (Texas A&M University)
Because of the lack of any empirical reference with which to compare predictions, validation of long-run linear programming models is extremely difficult. This paper reports two procedures for combining time-series data with results from a long-run linear programming supply model in order to make verifiable short-run predictions.

"Projecting State Agricultural Production Quantities with a Cobb-Douglas Programming Model." David L. Watt (USDA, Michigan State University) and George E. Rossmiller (Michigan State University)
A Cobb-Douglas programming model of Michigan agriculture sector production was developed for thirteen commodities using twenty-four input categories and tested for the period 1955–62. Input supply and commodity demand schedules are used by the algorithm to solve for input and output quantities by year.

"The Use Of Scenarios in ERS's Economic Projections Program." Leroy Quance (ERS, USDA)
As a general world food scenario, the Economic Research Service advocates a supply-demand management scenario with serious but manageable problems. By bracketing uncertainties ranges of future supply-demand attributes, scenarios permit a systematic analysis of emerging and recurring issues. Probabilities of alternative futures resulting from studied scenarios will also be estimated.

"The Ability of the Futures Market to Forecast Profit Margins in the Broiler Industry." David E. Kenyon and Neil P. Shapiro (Virginia Polytechnic Institute and State University)
Broiler integrators experience fluctuating profit margins. Expected net profit margins can be generated by using the corn, soybean meal, and iced broiler futures contracts with their appropriate basis estimates. The expected net profit margins based on these futures prices were found to be ineffective forecasters of actual profit margins.

"An Annual Projection Model for Selected Price Indexes and Expenditures Related to Food." Chung J. Yeh (ERS, USDA)
An ordinary least squares technique based on inputs derived from component models of the Economic Research Service's NIRAP system is used to project food prices and related indicators. Results indicate that food prices in the decade ahead will continue to rise but at a much slower rate than prices in general.

Issues and Techniques in Extension (John S. Bottum, Federal Extension Service, USDA, Chairman)

"Motivation of Professional Scholars: The Role of Administrative Evaluations." Russell L. Berry (South Dakota State University)
How to motivate professional scholars? Give them full freedom to seek the truth and report what they have found. This "freedom to" can only exist when there is freedom from improper evaluations and sanctions. Continuous evaluation with "one-shot" awards or punishment is recommended. Annual competitive evaluations destroy morale and motivation.

"Using Educational Television as a Delivery System for Teaching Futures Market Concepts." Larry D. Jones, D. Milton Shuffett, Steven Callahan, John C. Gamble, and Charles L. Moore (University of Kentucky)
Thirteen weekly programs on futures markets were taught to farmers using television as a delivery system. Agricultural economists were responsible for technical accuracy, while professional writers and announcers were responsible for communicating ideas. Five thousand individuals preenrolled in the series. More than half watched ten or more programs.

"An Extension Education Approach to Community Resource Development: Implications from Virginia's Title V Rural Development Program." Marilyn H. Grantham and Dennis K. Smith (Virginia Polytechnic Institute and State University)
Implications from Virginia's Title V program call for more involvement of local residents and extension agents in problem definition and program development. More in-service training is needed by local extension agents. An expanded body of research theory and tools is needed relative to all of the problems encountered.

Structure of Agricultural Economics Teaching Programs (Dean Tuthill, University of Maryland, Chairman)

"Computer Capabilities and Usage for Under-

graduate Grading and Reporting." Sandra Kay McDonald (Texas A&M University)
This paper reviews the latest computer application for scoring, reporting, and evaluating effectiveness of examinations. Strengths, weaknesses, and costs are all examined.

"Reflections on Graduate Training in Agricultural Economics for Asian Students." Ray W. Nightingale (ERS, USDA)
Program characteristics and locational advantage afford graduate students in agricultural economics at the American University of Beirut an exceptional training opportunity free of some of the generally existent dilemmas in U.S. international educational programs. The experience suggests a program design better suited for preparing Asian students for likely future careers.

"The Use of Electronic Calculators by Students in Examinations and for Course Assignments." Lyle P. Fettig (University of Illinois)
Potential benefits and problems associated with the use of electronic pocket calculators for course assignments and examinations are discussed and illustrated. Conditions necessary for the effective use of electronic calculators in learning situations, requiring the solution of new types of problems involving arithmetic, are suggested.

"Current Structure and Status of Undergraduate Programs in Agricultural Economics." Robert L. Beck, A. Frank Bordeaux, Jr., Joe T. Davis, Russell H. Brannon, and Loys L. Mather (University of Kentucky)
This paper reports the results of a survey of undergraduate programs in agricultural economics.The primary focus was on the current structure and status of agricultural economics programs, departmental characteristics and faculty involvement, and growth areas and new directions. Implications of some trends and developments are explored.

Energy (R. J. McConnen, Montana State University, Chairman)

"The Economic Impact of a New Electrical Plant on a Rural County: The Case of Sullivan County, Indiana." John Gordon and David Darling (Purdue University)
The economic impacts of a new electrical generating plant on a rural community were quantified using a partial budgeting model. Annual impacts were estimated over a fifteen-year period. Private sector impacts are positive throughout, but public sector impacts are negative in the early years before turning positive.

"The Economics of Solar Home Heating Systems for the Southwest Region." Thomas H. Stevens (New Mexico State University)
The probability of solar space heating systems being economically competitive with conventional systems is examined. The results indicate that solar systems are competitive with electric and LP gas systems in several locations throughout the Southwest. However, they are not competitive with natural gas systems under most market conditions examined.

"Interregional Structure of the United States Coal Economy." James D. Libbin and Michael D. Boehlje (Iowa State University)
A multiperiod mathematical programming model of the national coal economy is developed and used to appraise future interregional shifts in coal production. The effects of alternative sulfur dioxide emission standards on coal production (location and type of mining), the coal processing sector, transportation industry, and capital markets are analyzed.

"Determining Energy Requirements for Agriculture: Some Methodological Issues." C. Gopalakrishnan (University of Hawaii), N. A. Patrick (New Mexico State University), and W. J. Chancellor (University of California, Davis)
The current methodology for determining energy requirements in agriculture leaves much to be desired. This paper develops an alternate approach embodied in an energy-flow model for agriculture. It also identifies six dimensions crucial to the determination of energy needs of agriculture and examines their implications from a methodological perspective.

"Rural Electrification in India: Bio-gas versus Large Scale Power." Wallace E. Tyner (Cornell University) and John Adams (Maryland University)
In contrast to previous major studies, it is found that centralized power enjoys a cost advantage over local bio-gas generation. If, however, technical, administrative, and village equity problems are solved, 50,000 to 100,000 units might be installed in remoter villages.

Industry Research and Structure (Bob Olson, South Dakota State University, Chairman)

"The Impact of Collective Bargaining on Grower Returns and Processor Efficiency in the Ohio Concord Grape Industry." Dennis R. Henderson (Ohio State University) and John R. Schmelzer (University of Wisconsin)
Many potential economic benefits have been hypothetically attributed to collective bargaining by farmers. A case study measured pecuniary gains and their sources associated with voluntary collective bargaining in the grape industry. Results show positive integrative gains associated with price stability but no distributive gains nor improved grower-handler coordinative efficiencies.

"Mutual Benefits from Joint University-Agribusiness

Research." Lynn W. Robbins (University of Kentucky), Stephen B. Harsh, and John W. Allen (Michigan State University)
Universities and agribusiness firms are working as two almost entirely separate cultures. Fear of discriminating subsidization and classified information disclosure is among the objections blocking increased interaction. Carefully planned contracted research provides benefits to both components, negates collaboration costs, and demonstrates the desirability of encouraging other university-agribusiness cooperation.

"The Effect of Government Policy Instruments on the Market Structure of the Ohio Fluid Milk Processing Industry." Richard L. Kilmer (ERS, USDA) and David E. Hahn (Ohio State University)
Effect of market share and merger restrictions on seller concentration and related factors is explored using an intertemporal production-distribution model. Plant size constraints are predicated on Markovian transition probabilities. Policy instruments are found to have differing effects on size distribution, distribution patterns, costs, top four market share, and numbers.

"Market Performance in the United States Vegetable Oil Industry: An Application of Simulation for Market Analysis." R. McFall Lamm, Jr. (Virginia Polytechnic Institute and State University)
A simulation model of the processing sector of the domestic vegetable oil industry was used to estimate the rates of return for five products by months over the period from January 1974 to December 1975. The results indicated no great degree of market power in the industry.

"Optimal Number, Size, and Location of Milk Manufacturing Plants in the Southeast with Implications for Industry Policy." W. T. Boehm and M. C. Conner (Virginia Polytechnic Institute and State University)
The optimal number, size, and location of milk manufacturing plants in the Southeast was determined subject to seasonal fluctuations in production and practical restrictions on the assembly, movement, and processing of milk. Substantial technical efficiencies could apparently be gained from an industry wide reorganization that would permit the milk movement patterns shown in this research.

Water—Information and Management Issues (E. L. Michalson, University of Idaho, Chairman)

"Do Drouth Cycles Exist? Applications to Supply-Demand Analysis." J. Roy Black and Stanley R. Thompson (Michigan State University)
The evidence for the existence of "drouth cycles" in the U.S. Corn Belt and Great Plains is empirically tested using econometrics. An application to the forecast of U.S. seasonal average corn prices is presented. Some issues surrounding the existence of drouth cycles and alternative climatic models are discussed.

"The Economic Feasibility of Nuclear Desalination of Groundwater in New Mexico." Robert R. Lansford, Raymond J. Supalla, William D. Gorman, D. B. Wilson, Thomas H. Stevens, Bobby J. Creel (New Mexico State University), Lynn Gelhar, Marshall Reiter, Allen R. Sanford (New Mexico Institute of Mining and Technology), Stanley E. Logan, Richard Mead, William Schulze, Shaul Ben-David, and Fred Roach (University of New Mexico)
The economic feasibility of a proposed energy-water complex is examined. The complex was found infeasible because current desalting technology is too costly in comparison to any reasonable projections of water value. However, the concept of a nuclear energy park that uses brine water for cooling warrants further investigation.

"Value of Data Acquisition in Water Quality Management." Cleve E. Willis and Richard McAniff (University of Massachusetts)
This paper develops a Bayesian framework for estimating the value of information associated with water quality monitoring systems. This framework is demonstrated for an existing regional situation in western Massachusetts. It is shown how the empirical results obtained can be used in selecting "optimal" monitoring systems.

"Rural Residential Water Demand." O. C. Grunewald, David L. Debertin, and C. T. Haan (University of Kentucky)
This study proposes that demand management through pricing policies can be used to solve water supply problems. A demand function for water was developed using cross-sectional water data. The demand function was used in a simulation analysis to determine reservoir capacity needed to supply water for a rural community.

"Alternative Models for Estimating the Time-Series Components of Water Consumption Data." Hiroshi Yamauchi and Wen-yuan Huang (University of Hawaii)
Additive and multiplicative models are used to analyze the trend, cyclical, seasonal, and irregular components of water consumption time-series data. Evaluation of these components opens up important opportunities for improving on existing water management practices and for more intelligent evaluation of alternative policy measures.

Health, Consumption, and Estate Management Planning (Sam Cordes, Pennsylvania State University, Chairman)

"Effects of Economic Variables and Food Delivery Programs on Nutrient Intake." David W. Price,

Donald A. West, and Genevieve E. Scheier (Washington State University)
A sample of 849 Washington school children showed the national school lunch program to be increasing intakes of some nutrients for children receiving free lunches. Liquid assets and school breakfast participation influenced intakes of some nutrients, while current income had little impact. The effects of food stamps are inconclusive.

"The Economics of Consumer Protection." Rachel Dardis and Diane Hyman (University of Maryland)
There has been increased interest in consumer protection in recent years, particularly in the area of product safety. This paper investigates the role of cost-benefit analysis in determining whether mandatory safety standards are in the public interest and applies such analysis to an evaluation of flammability standards for children's sleepwear.

"Estimation of Factors Affecting Rural Health and Legal Services Needs—A Comparison of Methods." Douglas Chiriboga and Cleve Willis (University of Massachusetts)
This paper summarizes the limitations of least squares estimation procedures for dichotomous dependent variables and outlines the essential features of probit analysis as an alternative. The results of two sets of empirical estimations using least squares and probit are compared. Probit results are superior in at least one case.

"A Simple Human Investment Model for Analyzing Personal Health Investments: Theoretical Development." Thaine H. Allison, Jr. (Inland Countries Comprehensive Health Planning Council, San Bernardino)
The general case of human investment occurs when some portion of income is devoted to investment over the full life of the investor. This simple theoretical micromodel is expanded to identify how the individual investment decisions are made to maximize utility where investment enters the utility function.

"A Decision Model for Estate Management Planning." Michael Boehlje (Iowa State University)
A decision model that evaluates how well alternative legal and financial tools satisfy specified estate management goals is developed. The results of computer simulation of a case estate are presented to illustrate how the model could be utilized as an operational tool of an estate management service.

Regional Development and Planning (Daniel Swope, Agricultural Research Service, USDA, Chairman)

"Developing Economic Information for Regional Planning: A Case Study." M. C. Conner and Dilip Pendse (Virginia Polytechnic Institute and State University)
A comprehensive economic information package was developed within a constrained time frame to help a planning district in Virginia formulate its development strategies. The study involves an analysis of several major aspects of the local economy and a coordinated evaluation of the regional development potentials using an input-output model.

"Adapting Shift-Share Analysis to Rural Development Planning." Gerald Marousek (University of Idaho)
Shift-share analysis of population changes in northern Idaho is presented as an early stage planning tool in rural development. It enables isolation of a national industry's growth relative to the total economy and a local industry's growth in relation to the national industry. This knowledge can be valuable to local development planners.

"Extending the Life Cycle of an Old Product—A Source of New Rural Industry." Daniel A. Swope (ARS, USDA)
Establishing plants with modern equipment to produce sorghum sirup would provide new industry and employment opportunities in rural areas. Adopting improved harvesting and handling equipment would increase labor efficiency and returns to farmers. Availability of assured supplies of higher quality sirup would meet blenders' requirements and should increase consumer use.

"An Evaluation of the Impact of Growth on the Urban Fringe Using Two Methods of Estimating Public Service Costs." Robert E. Lee II (Illinois Department of Conservation) and Robert L. Christensen (University of Massachusetts)
Population growth on the urban fringe gives rise to both financial and land-use planning problems for communities. This paper describes differences in normative land-use and housing patterns and the financial impacts resulting from use of two alternative approaches for estimation of municipal costs.

Agricultural Trade and Development Policy Issues (Lee Blakeslee, Washington State University, Chairman)

"Price Supports versus an Equilibrium Exchange Rate: A Comparison of Income Distribution Consequences." Mauro Lopes and G. Edward Schuh (Purdue University)
Floyd's estimates of the effects of farm price supports on the returns to land and labor in agriculture are used to evaluate the effect of the overvalued dollar on relative factor returns. The results suggest that labor was forced to bear the burden of disequilibrium in the foreign exchange market.

"Grain Exports Possibilities as a Function of Domestic Human and Animal Nutrition." Doeke C. Faber, Earl O. Heady (Iowa State University), and Steven T. Sonka (University of Illinois)

The study indicates the possibilities that exist for alleviating the world food shortage through changes in human diets and animal production patterns. Using a linear-programming model, it is found that exports of wheat, feed grains, and soybeans can be more than doubled relative to the 1971–73 average quantities exported.

"An Extension Approach to Discussion of Bilateral Grain Trade Agreements." Ed Watkins and E. Dean Baldwin (Ohio State University)
Proponents of trade agreements argue that these agreements help stabilize grain and meat prices. Opponents argue that these policies distort world grain markets. To identify the issues underlying these agreements, this paper examines the annual U.S. grain supply, export volumes, variations, destinations, and the theoretical impact of trade agreements.

"Grain Reserves—An Evaluation of National and International Policies." Anne del Castillo (University of Maryland)
A successful international grain reserve system requires the consensus of the world's major grain producers and consumers. The policy recommendations from the United States, the European Community, and the Food and Agriculture Organization are evaluated and contrasted.

"The Famine Prevention and Freedom from Hunger Amendment: Issues and Compromises in International Development Policy Making." Harold D. Guither (University of Illinois)
The Famine Prevention and Freedom from Hunger Amendment is part of the International Development and Food Assistance Act of 1975. Its purpose is to enlist U.S. agricultural colleges to increase food supplies in developing countries. It could become landmark legislation. Much will depend upon public support and government policies.

Subjects in Agricultural Marketing and Price Analysis (Bruce Wright, Economic Research Service, USDA, Purdue University, Chairman)

"Variation in Measurement of Corn Grade Factors." T. E. Elam and L. D. Hill (University of Illinois)
The USDA grain grading system has drawn considerable attention due to allegations of misgrading. An analysis of the potential role of random error in the grading system is presented. It is concluded that random variation may be a major cause of changes in grain grades under conditions of repeated sampling.

"Risk Reduction Through Marketing Frequency." Joseph C. Meisner (University of Missouri-Columbia)
Market price risk is a major concern to the agricultural firm. This study examines the distribution of profits and loss for cattle-feeding operations. Frequency of marketing over a nine-year period is varied from monthly to one time yearly. Data suggests increased frequency of marketing can greatly modify risk.

"Efficiency Analysis of Pricing Alternatives for Long-Term Contracts." Steven T. Buccola (Virginia Polytechnic Institute and State University) and Ben C. French (University of California, Davis)
Market, cost-plus, and sales-minus prices for a cooperative's long-term marketing contracts are considered in an E-V framework. A simulation model generates prediction probability moments from historical and subjective data. Optimal purchase and sales portfolios are interdependent; both are highly responsive to cost-plus and sales-minus parameters.

"Analysis of the Impact of Market Characteristics on City Food Prices." Gerald E. Grinnell, Terry L. Crawford, and J. Gerald Feaster (ERS, USDA)
Variation in retail food prices, measured by the consumer price index, among nineteen large U.S. cities using cross-section analysis of time-series data was related to distance, income, wages, and per capita food store sales. Market concentration effects were sensitive to model specification. Models including only market concentration are subject to misspecification.

"Transmission of Week-To-Week Changes in Choice Beef Prices between Farm, Carcass, and Retail Levels." Richard A. King (North Carolina State University)
Rates at which weekly changes in farm prices were transmitted to carcass and retail levels from October 1973 through September 1975 are compared using first difference and polynomial distributed lag models. While farm and carcass prices were closely associated, the retail price response is shown to extend over several weeks.

Resource Planning, Development, and Management—Part A (Nelson Bills, Economic Research Service, USDA, Cornell University, Chairman)

"Subsidizing Agriculture in Urbanizing Regions." Barry C. Field and P. Geoffrey Allen (University of Massachusetts)
Conventional welfare principles are used to examine regional programs of agricultural protection. Optimal subsidies depend on the degree of irreversibility of contractions in regional output. Because of input substitution, they are lower when applied to the irreversible input than when on output. Income redistributions from consumers to producers are considered.

"A Game Theory Approach to an Environmental Land Use Problem." David Y. Chen (North Carolina A&T State University)

An attempt exploring the application of a two-player nonconstant sum static game with a built-in decision scheme is made to a rural town and a major phosphate operation in North Carolina. Comparison on the discounted net benefits suggests that mutual cooperation be the best policy.

"Social Returns to Containing and Eradicating Witchweed in the United States." Gerald E. Plato and Peter M. Emerson (ERS, USDA)
Ex ante estimates of returns to U.S. society of at least 35% from two alternate U.S. Department of Agriculture witchweed programs were found. Witchweed is a semiparasitic plant that reduces corn and grain sorghum yields. Critical elements determining returns are witchweed's potential spread rate and program costs.

"Private Property, Market Trade, and Wildlife Conservation." Jeffrey C. Stier and Richard C. Bishop (University of Wisconsin)
It has been suggested that a policy of wildlife conservation based upon private ownership and market exchange of wildlife and wildlife products would be more efficient than the traditional protectionist policy. However, the economic implications of such a policy indicate that it may be of limited value for conserving wildlife.

Production Changes in Developing Countries (Donald W. Larson, Ohio State University, Chairman)

"A Methodology for Measuring Benefits of Integrated Rural Development Projects." J. Gerald Feaster (ERS, USDA)
A regression model for measuring the impacts of the components of regional development projects was tested using data from Colombia. Credit, technical assistance, and roads were among the components found to have significant effects on farm development. Other variables included in the model were time and farm size.

"The Effects of HYV on the Regional, Seasonal, and Varietal Changes in Rice Production in the Philippines." Ernesto C. Lucas, T. T. Williams (Southern University), and Leah B. Sereno (University of the Philippines)
The objective of this study is to evaluate the impact of the high yield varieties on the traditional rice agriculture in the Philippines. The results indicate decreased regional specialization in rice production, increased seasonality of harvest, and displacement of traditional varieties for high yield varieties. These changes affect marketing, pricing, and transportation of rice.

"Agricultural Development in India's Districts: Sources of Productivity Differences in Rajasthan, 1971." Balu Bumb (University of Maryland)
A factor analysis model was used to study differences in agricultural productivity in Rajasthan, India. Because of multicollinearity among variables, factor analysis yielded better results than regression models. Besides labor, animal power, and capital, the importance of infrastructure, technology, and ecology variables in explaining productivity differences was established.

"Corn Production by Tenure Types in Nicaragua." Waldo Hooker and Melvin G. Blase (University of Missouri-Columbia)
The impact of type of tenure on the production of selected crops in Nicaragua was analyzed. Security of tenure was found to be closely related to output as expected. In addition, the productivity of selected inputs was estimated in the production function analysis by tenure groups. Policy recommendations were offered.

Risk and Uncertainty in Agricultural Production and Marketing (George Irwin, Farm Credit Administration, Chairman)

"Incorporation of Risk Variables in Econometric Supply Response Analysis." W. Bruce Traill (Cornell University)
A methodology is developed for estimating supply equations that specify risk variables in terms of deviations between expected and actual outcomes. The method, which is iterative in nature, allows considerable flexibility in selecting the form of the lag structures and precisely defining the risk variables. Empirical results for onion acreage response are presented.

"A Risk-Return Analysis for the Midwest Cattle Feeder." Larry D. Trede and Michael D. Boehlje (Iowa State University)
With increased price volatility, cattle feeders are becoming increasingly concerned about risk management. This paper utilizes a marginal risk constrained linear programming model to analyze the key variables affecting the profits of the midwestern cattle feeder. Implications for enterprise organization and specialization versus diversification are developed.

"A Risk Programming Model of Beef-Cow Forage Production." R. A. Schoney (University of Wisconsin) and T. K. White (Purdue University)
A linear programming model was developed to examine the potential impact of hay stackers on beef-cow farms. The model included three decision stages and risk generated by weather-related variables on three parameters: field days, haying days, and forage yields. Optimal annual, average, and standard deviation of returns were derived.

"The Impact of Uncertainty on Pesticide Application." Gershon Feder (World Bank)
Uncertainty is introduced into several components of a simple pest management model. Risk aversion

leads to higher quantities of pesticides and to a decline in economic thresholds, implying higher frequency of applications. The reduction of uncertainty via better dissemination of information is thus recommended.

"The Expected Income-Risk Trade-Off Among Corn Belt Crop Farmers." Lars Brink (Purdue University)
The risk aversion coefficient in the expected utility function of a sample of Corn Belt crop farmers was estimated. The measure of risk was similar to the mean absolute deviation. In general, the estimate was close to zero, and the sensitivity of the farm plan to varying parameters was low.

Factor Markets and Productivity (Burt Sundquist, University of Minnesota, Chairman)

"Measuring Labor Productivity: An Economy-Wide Study of the Production of Food for Personal Consumption." Eric C. Howe, Gerald E. Schluter, and Charles R. Handy (ERS, USDA)
Labor productivity for each of four components of personal consumption expenditures for food is measured for four selected years. The labor productivity estimates include both direct and supporting labor needs because, using input-output analysis, it was possible to identify labor inputs irregardless of their sectoral location in the economy.

"Quantifying Management as a Production Cost." Gary S. Kemph and Gerald D. Schwab (Michigan State University)
Congress has directed that cost of production figures be established for selected agricultural commodities. Pricing of management is required in these cost estimates. Five alternative calculations for estimating management costs are presented to illustrate the wide variation in cost of production that can result from this one item.

"Measuring Changes in Economic Well-Being of Factor Owners: Approaches and Problems." Jagjit S. Brar (Washington State University)
This study for the first time underscores empirical problems encountered in the estimation of changes in economic well-being of factor owners. Changes in well-being were estimated by different approaches. Estimates exhibited significant differences depending upon the length of run of supply curve, concept of economic rent, and elasticity of supply.

"Whose Skills are Demanded? An Empirical Study of the Distributional Impacts of U.S. Forest Service Policies on Local Job Markets." James Baskett and Harry Ayer (University of Arizona)
Estimates are made of the impact of alternative U.S. forest service policies on the distribution of jobs among skill levels of people in local rural communities. The analysis uses primary data and employs several refinements of interindustry analysis. Policy implications pertaining to the income (skill level) distribution problem are given.

Fishery and Marine Resources (Fred Prochaska, University of Florida, Chairman)

"Factors Affecting Monthly Florida Mullet Prices with Special Emphasis on Landings and Market Development." James C. Cato (University of Florida)
Florida mullet prices vary seasonally due to several factors. Particular emphasis is given to the effect of lagged quantities landed on prices and the resultant price flexibilities. Market development programs have also shifted demand. Industry implications of these effects are also discussed. A polynomial distributed lag model is used.

"Stock and Congestion Externalities in the Fishery: The Case of the Georges Bank Scallop." Jon M. Conrad (University of Massachusetts) and Marilyn A. Altobello (ERS, USDA)
Estimation of U.S. and Canadian yield functions in a bioeconomic model of the Georges Bank scallop fishery indicated stock and congestion externalities. The latter resulted in nonconcavity of the combined yield function, thus generating the possibility of steady-state corner solutions where one nation would be eliminated from the fishery.

"Consumer Surplus, Producer Surplus, Is there a Country Surplus?" Fred L. Olson (U.S. Department of Commerce)
A description of the theoretical characteristics of the developing market for fishery resources used by distant water fleets as a result of the Fishery Conservation and Management Act of 1976, P.L. 94-265, and the Third Law of the Sea Conference, in progress.

"Bioeconomic Models of Marine Recreational Fishing: Some Implications for Policy and Future Research." K. E. McConnell and J. G. Sutinen (University of Rhode Island)
An optimal control bioeconomic model of a recreational fishery is developed and examined for insights into policy and research issues. Important areas for future economic research include the role of catch per outing in demand for recreational fishing and the impact of stock changes on the catch per outing.

Development Processes Outside the U.S. (T. T. Williams, Southern University, Chairman)

"East African Markets and Tanzanian Policies for Pricing and Plant Location—Livestock and Meat." Donald E. Farris, Gregory M. Sullivan (Texas A&M University), and Kenneth W. Stokes (USAID-TAMU/Tanzania)
Tanzania pricing policies for livestock and meat fail to provide the necessary seasonal, spatial, and qual-

ity price differences to achieve the objectives of national policy. A linear programming model is used to provide guides for efficient pricing and packing plant location. Plants in the interior would save $10 per head.

"Factors Affecting the Supply of Off-Farm Labor Among Small Farmers: The Case of Taiwan." Donald W. Larson and Hung Yu Hu (Ohio State University)
The issue of low income among small farmers in a developing agriculture is discussed. An off-farm labor supply function for rural Taiwanese households is estimated for 329 farm families. Dual employment was found to be a viable alternative to effectively deal with the low income problem of small farmers.

"The Schools of Thought on Small-Farm Development in the Developing Countries." Marcelino Avila and Melvin G. Blase (University of Missouri)
The paper presents an informative analysis on the most important contributions to the literature on small-farm development in the developing countries by dividing them into four schools of thought: community development, "green revolution," integrated rural development, and collectives. Subsequently, selected observations on small-farm development strategies are made.

"Labor Productivity on Small Farms: The Case of Nicaragua." Gustavo Arcia and Philip F. Warnken (University of Missouri-Columbia)
This study examines labor productivity of hired and family labor on small farms in Nicaragua. Two hypotheses are tested relating to the MVP_L and AVP_L with respect to the wage rate. Policy implications are drawn regarding rural to urban migration and rural and urban unemployment for developing nations.

"Modeling Transportation and Storage Systems in Developing Areas as Capacitated Networks." Charles L. Wright and Richard L. Meyer (Ohio State University)
Capacitated network models are presented as more appropriate instruments for studying commodity transportation-storage systems in developing areas than traditional linear programming models. Illustrations incorporate realistic features of capacity constraints, multiple transshipment points, storage, intermodal transfer costs, and convex costs. A solution is obtained using the efficient Fulkerson algorithm.

Computers as Teaching Aids (Melvin R. Janssen, Economic Research Service, USDA, Chairman)

"A Teaching Package for Portfolio Selection Analysis Using a Quadratic Programming Approach." Kerry K. Litzenberg and James G. Beierlein (Purdue University)
The Markowitz portfolio theory has been used by economists for many years. To apply this procedure to a classroom situation requires students well versed in portfolio theory and quadratic programming. The procedure described in this paper removes one or both of these barriers and is adaptive for classroom use.

"Computer Graphics: An Educational Tool for Understanding Agricultural Production Functions." David L. Debertin, Angelos Pagoulatos, and Garnett L. Bradford (University of Kentucky)
Computer graphics can be used as a tool for teaching courses in agricultural production economics. Computer graphics enables students to generate three dimensional illustrations of surfaces of two input production functions. The role of second order conditions for ensuring solutions to optimization problems can be illustrated with computer graphics.

"Teaching the Policy-Making Process." Fred C. White and Sherry K. White (University of Georgia)
Simulation, an exciting technique that places the student in the role of economist and policy maker, has been used in undergraduate agricultural policy classes to teach the policy-making process. Simulation allows students to make critical judgments on important policy issues. This realistic approach is described in this paper.

Theory and Technique (Ben French, University of California, Davis, Chairman)

"The Effects of Real Multiplier versus Inflationary Effects on Output and Income Generation in Input-Output Models." Gene K. Lee and Gerald Schluter (NEAD, ERS, USDA)
A modified input-output model that incorporates price changes as well as changes in the volume of final demand demonstrates that changes in the price and changes in the volume of final demand have different effects on the economy but also influence different segments of the economy.

"Adapting Portfolio Theory for Asset Indivisibility: A Conceptual Approach." Lindon J. Robison (ERS, USDA) and Peter J. Barry (Texas A&M University)
Portfolio theory is used to explore the kinds of risk-return effects induced by investments in indivisible assets. Risk-return economics require higher levels of return and risk as the size of the fixed investment increases, and portfolio choices can be limited using Baumol's E-V criterion.

"Orthogonalization and Variable Deletion in Regression Analysis: The Problem Revisited." Ron C. Mittelhammer and John L. Baritelle (Washington State University)
This paper briefly reviews artificial orthogonalization and component deletion in regression analysis.

Confusion exists over which elements to delete in the orthogonal frame of analysis. This paper developed the theory of component deletion via the characteristic root and t-value and interprets the meaning of each criterion. A simulation model is employed.

"A Method for Computing Optimal Production, Investment, Financing, and Consumption Strategies under Uncertainty." James F. O'Connor (University of Iowa)
Under price and production uncertainty, expected utility maximizing strategies for production, investment, financing, and consumption can be computed by a combination of quadratic programming and algebra when the entrepreneur displays constant absolute risk aversion and faces linear programming production technology and when the uncertain quantities are normally distributed.

"The Use of the Gini Ratio in Measuring Distributional Impacts." Charles H. Riemenschneider (Michigan State University)
Economists often use the Gini ratio for measuring inequality in income or program benefit distributions without fully understanding its implications and limitations. This paper delineates some of the limitations in the use of the Gini ratio as commonly calculated and examines several new techniques for calculating the Gini ratio.

Estimation Methods (Rueben Buse, University of Wisconsin, Chairman)

"A Test for the Statistical Significance of a Frontier Production Function in Dairying." Bill R. Miller (University of Georgia) and Clifford M. Carman (ERS, USDA)
The authors hypothesize that a frontier production function is influenced by some unspecified set of information. Using a multivariate discriminate model, they test for specification error of the function. They conclude that a frontier function appears to effectively sort dairy farms into groups that differ in a statistically significant manner.

"Improved Estimation of Cattle Slaughter Through Generalized Least Squares." Thomas Spreen and Glenn Nelson (Purdue University)
The problem of improving the estimation of cattle slaughter is addressed by making suggestions for a better model specification and exploiting more fully the available statistical information through use of generalized least squares. The results are contrasted with ordinary least squares estimation and illustrated by estimating withholding in 1973.

"A New Approach to Small Area Crop-Acreage Estimation." Harold F. Huddleston (SRS, USDA) and Robert M. Ray III (University of Illinois)
This research was undertaken to assess the practicalities of improving the accuracy of crop acreages using remote sensing data. In obtaining state estimates, small area estimates are made that are partitioned into county estimates. The accuracy of the small area estimates is significantly improved, leading to useful county estimates.

"Stochastic Specification of Production Functions: Econometric Convenience or Nonsense?" Rulon D. Pope and Richard E. Just (University of California, Berkeley)
The stochastic specification of input-output response is examined. Postulates are set forth that seem reasonable on the basis of a priori theorizing and observed behavior. Commonly used formulations are restrictive and may lead to inefficient and biased results. A function that satisfies the postulates is suggested.

Wastes—Issues and Utilization Alternatives (Gerald Horner, Economic Research Service, USDA, University of California, Davis, Chairman)

"Vector Optimization for Selecting Municipal Sludge Disposal Systems." Bruce E. Lindsay and Cleve E. Willis (University of Massachusetts)
An application of the constraint method of vector optimization is used to evaluate alternative sewage sludge disposal systems within a multiobjective decision-making framework for the metropolitan district commission area of Boston. The objectives of economic efficiency, environmental impact, and uncertainty associated with impact were selected for this investigation.

"Equity and Efficiency in Pricing Local Public Services: The Case of Wastewater." David H. Peterson and Daniel W. Bromley (University of Wisconsin)
Pricing decisions for local wastewater services can play a crucial role in the attainment of efficiency with equity. Normative judgments about equitable service should include concepts of ability-to-pay across users of the service and concepts of spatial equity. The determination of a price for wastewater service, using the objectives of efficiency, equity, and simplicity, may better suit the goals and policies of local officials than the traditional determination of price through the cost-of-service method.

"Partial Technology Assessments of Products Derived from Tannery Unhairing Effluent for Use in Poultry Rations Using Linear Parametric Programming Techniques." Harold H. Taylor (ERS, USDA) and Reed D. Taylor (Ohio State University)
The possible usefulness of products derived from tannery unhairing effluent for use in poultry rations were analyzed using linear parametric programming techniques. Intrinsic demand curves obtained indicated that these products could compete with other ingredients in poultry rations provided that production costs do not exceed acceptance level prices.

"An Economic Analysis of the Utilization of Municipal Wastewater for Crop Production." Lee A. Christensen (NRED, ERS, USDA)
Sensitivity analysis was used to estimate changes in farm revenues utilizing waste-water irrigation. Variables evaluated were yield response, rotations, prices, irrigation costs, and cost sharing. Corn was the most profitable crop evaluated, soybeans the least profitable. Net farm revenues were evaluated assuming alternative cost sharing levels by the waste supplying municipality.

"Economics of Nonmetropolitan Solid Waste Resource Recovery: A Case Study and Some Extensions." Mark Luttner (Environmental Protection Agency) and Fred Hitzhusen (Ohio State University)
A nonmetropolitan coal burning steam-electric plant in northeastern Ohio was analyzed to determine the technical and economic feasibility of converting the plant to solid waste as a supplementary fuel. Benefit-cost sensitivity analysis showed the proposed system economically feasible under a wide range of technical and economic parameter values.

Regional Development—Strategies, Indicators, and Impacts (Larry Morgan, Texas A&M University, Chairman)

"Nonmetropolitan Job Creation in a Post-Industrial Society: Problems and Prospects." Stephen M. Smith and Glen C. Pulver (University of Wisconsin-Madison)
Employment trends, population and industry movements, and changing economic development goals are examined. The prospects of various industrial sectors for meeting nonmetropolitan employment and development goals are assessed. In conclusion, particular service sector industries may provide a more solid base for long-run job creation and economic growth strategies.

"An Analytic Comparison of Multivariate Regional Rural Development Economic Well-Being Indices." Richard A. March and Dennis K. Smith (Virginia Polytechnic Institute and State University)
Four different multivariate indices of economic well-being were computed and compared for Virginia localities. These indices were highly correlated. Multivariate techniques should use specific problem related variables. A simple income-based index is as valid as a multivariate index incorporating large masses of intercorrelated data.

"Trade Interdependencies: The Case of Alaska and Washington." Kenneth L. Casavant (Washington State University) and Wayne C. Thomas (University of Alaska).
Alaska's economic activity and Washington's geographical proximity have created strong trade interdependencies. This paper presents findings as to the impact of, and opportunities for, more trade between the two states, as derived from an historical review, an input-output model, a profile of water movements, and a trade barriers survey.

"Toward a National Program of State and Regional Agricultural Safety and Health Statistics." Conrad F. Fritsch and John M. Zimmer (ERS, USDA)
A national program of state and regional occupational safety and health data can improve the information base from which proposed Occupational Safety and Health Act standards are discussed. Such data also provide the basis for documenting state safety and health education program content. Two data sources are evaluated for usefulness toward meeting these objectives.

Transportation (Orlo Sorenson, Kansas State University, Chairman)

"Demand for Freight Cars in the Movement of Grains." Erhardt O. Rupprecht, Jr. (NEAD, ERS, USDA)
The recent Railroad Act calls for rates reflecting peak demands. Carloadings of grain exhibit peaking and smoothing out movements could reduce the grain car fleet needed. However, this measure may not be entirely suitable in framing a pricing policy. Increased storage capacity would offset savings from a smaller car fleet.

"Changing Transport Demands by Agricultural Shippers in Response to Rail Restructuring." Arvin R. Bunker (ERS, USDA)
Changes in marketing-transportation activities in response to rail abandonment were evaluated for three alternative scenarios using a mathematical programming model. The total bill, ton miles of traffic by mode and highway type, highway maintenance costs, and changes in grain-fertilizer transportation were measured and related to the three scenarios.

"Simulation Analysis of Export Grain Flows Through Gulf Ports." Jerome J. Hammond (NEAD, ERS, USDA) and Michael S. Salvador (Ernst and Ernst)
A simulation model is used to determine circumstances that may constrain the export of grains through U.S. gulf ports. Results of analyses indicate that there is adequate capacity for increased exports of grains through these ports. Congestion does occur but diminishes substantially with increases in elevator-operating hours.

"Waterborne Transportation Benefits Received by Iowa Corn Farmers from the Mississippi River." Freeman K. Buxton (AMS, USDA)
Grain farmers along the upper Mississippi River receive low-cost water transportation benefits. Therefore, for water benefit continuation, Locks and Dam No. 26 near Alton, Illinois, must be repaired. This paper shows that low-cost barge rate

benefits are reflected back to eastern Iowa farmers in terms of prices received.

"Improving Michigan's Rail Service Through Group Action." Michael Patrick (Michigan State University)
Abandonment has been the traditional solution to the light-density rail line problem. Alternatives to abandonment exist, however. This paper argues that analysis and understanding of the interrelationships between carriers and shippers can lead to policies promoting improved rail service, increased rail shipments, and revenues on many light-density lines.

Impacts of Agricultural Trade on the U.S. (B. H. Robinson, Clemson University, Chairman)

"The Changing Structure of U.S. Trade: Implications for Agriculture." Antonio Brandao and G. Edward Schuh (Purdue University)
There has been a major change in the structure of U.S. trade, with the deficit on the account in nonagricultural trade becoming increasingly large while the surplus in agricultural trade simultaneously grows. The paper suggests some explanations for this phenomenon and draws implications for future policy.

"The Domestic Welfare Effects of U.S. Wheat Export Controls." Shun-Yi Shei and Robert L. Thompson (Purdue University)
A framework is developed to evaluate the domestic welfare effect of export controls. By imposing export restrictions on wheat in a short crop year, the United States could gain sizable short-run welfare benefits, export earnings could be substantially increased, and, unless the government intervenes, exporters reap most of the benefits.

"An Analysis of the Effects of Alternative U.S. Dairy Import Policies." Larry Salathe, W. D. Dobson, and G. A. Peterson (University of Wisconsin-Madison).
Wisconsin farm milk prices initially would fall by 16% if butter and cheese imports rose to 25% of U.S. requirements. Within four years milk prices would recover. But this recovery would occur only after 10% of the state's dairy farmers were forced out of business by the larger imports.

"Effects of Changes in the Level of U.S. Grain Exports." James N. Trapp and Stanley R. Thompson (Michigan State University)
The magnitude and duration of economic responses in U.S. crop and livestock markets to increased grain exports during 1972 are examined using an agricultural sector simulation model. In light of the 1972 case, consideration is given to the effectiveness of alternative government stock levels in "cushioning" grain export "shocks."

"The Impact of Trade Policies on the Demand for and Revenue from U.S. Feed Grains." Francis Walker and Kleo-Thong Hetrakul (Ohio State University)
U.S. exports of and total revenue from feed grains depend on trade policies of the United States, the importing countries, and other exporting countries. U.S. export demand functions for each of four importing countries are estimated. The impacts of selected trade policies on feed grain exports and revenue are determined.

Resource Planning, Development, and Management—Part B (Verner Hurt, Mississippi State University, Chairman)

"Investment in Information and Production of Natural Resources—A Stochastic Control Approach." Bruce L. Dixon and Richard E. Howitt (University of California, Davis)
Production from unexploited natural resources is of increasing concern to policy makers. Currently, optimal resource production models ignore the effect of uncertainty about resource stocks and the production process. The stochastic control formulation explicitly derives the conditions of optimal resource production under uncertainty and the cost of uncertainty in production.

"Economic Implications of Entropy and Materials Balance in Managing Exhaustible and Nonrenewable Resources." Angelos Pagoulatos (University of Kentucky)
From the extension and fusion of the entropy law and the materials balance, the economic implications of physical constraints in managing exhaustible resources are identified. Exhaustion is exemplified with the decreased availability of options of management. The trade-offs between options, technical efficiency, and uses in resource conversion processes are derived.

"An Analysis of the Opportunity Costs of Channelization and Land-Use Change in the Obion-Forked Deer River Basin." George F. Smith and M. B. Badenhop (University of Tennessee)
The value of floodplain lands in agricultural use following channelization and the resulting foregone value of these lands were estimated. The latter estimates were incomplete because of the inability to predict effects on potentially important parameters. Estimated differences provide a threshold for decision making. Policy implications are discussed.

"Improving the Framework for Estimation of Agricultural Benefits of Small Watershed Projects." Robert B. Jensen and Leonard A. Shabman (Virginia Polytechnic Institute and State University)
Techniques of agricultural benefit estimation for small watershed projects have recently become the focus of increasing study and controversy. An alternative approach to agricultural benefit estima-

tion is compared to current techniques on both a general level and by reference to a case study. Improvements in estimation techniques may be possible.

Trends and Factors in International Trade and Development (Philip Warnken, University of Missouri, Chairman)

"Brazilian Trade Policy and Its Impact on the Regional Distribution of Income." Marshall A. Martin and G. Edward Schuh (Purdue University)
Brazil's trade policies have affected regional income distribution. In the 1950s a sizable flow of capital was transferred into the state of Sao Paulo from the rest of Brazil, especially from the Northeast. More liberal trade policies and higher world commodity prices reversed the interregional resource flow in the 1960s.

"The U.S. Sugar Position in the World Sugar Economy." Ahmed Abou-Bakr (FDCD, ERS, USDA) and Albert Harrington (Washington State University)
Different marketing possibilities that would face the U.S. sugar industry are investigated. The U.S. sugar industry is competitive at a price that results from a world stocks-consumption ratio of 20%. At a price resulting from 30% stock-consumption ratio, the U.S. domestic sugar industry is clearly not competitive.

"Estimates of Income Coefficients of Final Demand for Food in Japan." Bruce L. Greenshields (ERS, USDA) and Kent B. Gates (College of William and Mary)
Estimates are made for both short-run and long-run marginal propensities to consume and income elasticities of demand for food. Consumers responded inelastically in the short run, but there was a positive, elastic response in the long run for several commodities and a negative, elastic response with respect to expenditures on rice.

"Agricultural Imports by Major Developing Countries—Their Growth in the Last Decade and Prospects for 1976." John B. Parker, Jr. (FDCD, ERS, USDA)
India was the leading importer of agricultural commodities among developing countries during nine of the last ten years, but in 1976 Egypt and South Korea are likely to move ahead of India. Other contenders for leading positions among food importers of developing nations include Iran, Iraq, Saudi Arabia, and Indonesia. Rapid growth in food imports by developing countries creates new opportunities for U.S. agricultural exports.

Structure and Organization of Agriculture (Kenneth R. Krause, Economic Research Service, USDA, Chairman)

"Seed Corn Purchasing Behavior of Corn Growers." David E. Hahn (Ohio State University)
Key factors affecting seed corn purchasing habits of farmers were examined. Hybrid performance was the primary differentiating measurement used by growers. Relative importance of alternative information sources for assessing performance was evaluated. Test plots, neighbors and other farmers, university extension personnel, seed corn dealers, and advertising was the rank order.

"Part-Time and Full-Time Farm Operators: Some Comparisons." K. C. Schneeberger (University of Missouri), Sam Comer (Tennessee State University), and Richard Edwards (ERS, USDA, Tennessee State University)
Are part-time and full-time farms different in organizational and operational characteristics? Do operators respond differently to changing economic and technologic conditions? Large, full-time farmers reported practices and attitudes most consistent with efficiency and profit maximization. Part-time farmers had an investment strategy, and small, full-time operators appeared survival-oriented.

"Management, Capital Structure, and Farm Firm Growth Revisited." George F. Patrick (Purdue University)
Three levels of managerial ability, capital availability, and interest rates were simulated for periods comparing the 1960s and 1970s. Managerial ability was the major determinant of firm growth, but impacts of capital availability and interest rates were greater under conditions of the 1970s than they were in the 1960s.

"Identification of Growth Potential for Locally Owned Farmer Cooperatives." Gary T. Devino, Stephen E. Mathis, and Francis P. McCamley (University of Missouri-Columbia)
Eleven financial ratios associated with firm growth were utilized in a linear probability model for predicting growth of locally owned farmer cooperatives. The models developed were accurate in predicting growth 82% of the time for High Plains cooperatives and 73% of the time for Midwest cooperatives.

Award-Winning Theses

Hu, Hung-Yu. "Analysis of Factors Affecting Supply of Off-Farm Labor Among Taiwanese Farmers." M.S. thesis, Ohio State University, 1975.

The objective of this study was to explore the main factors affecting farmers' off-farm labor supply in Taiwan. The conclusions are: (*a*) Taiwan's agriculture has changed from a unimodal pattern to a bimodal pattern, (*b*) eight quantitative variables and two dummy variables significantly affected farmers' off-farm labor supply, and (*c*) the elasticity of off-farm labor supply with respect to the ratio of nonfarm wages to net farm income for the pooled sample was inelastic. However, after classifying into two subgroups, the elasticity of off-farm labor supply for "small" farmers was significantly higher than that for "larger" farmers.

Pieri, Renato G. "The North American-Japanese Pork Industries: An Economic Analysis." M.S. thesis, University of Guelph, 1975.

The main objective of this study was to develop a quarterly recursive programming model of the Japanese-North American pork industries, including the spatial and temporal aspects of the sector, for use in evaluating policy alternatives.

The study outlines the structure of the Japanese pork industry and develops a five-region (eastern Canada, western Canada, United States, Japan, and the rest of the world) quadratic programming model that is able to incorporate the Japanese pork price stabilization policy that includes import quotas, a variable duty, and an *ad valorem* duty. Supply, consumption, and storage functions were estimated using data from 1961 through 1974.

The validated model was used to analyze the effects of exchange rate variations, Japanese domestic agricultural policies, and long-term export contracts on the volume and origin of North American-Japanese trade.

Staatz, John. "The Economic and Nutritional Impact of Changes in Agricultural Production Patterns: The Case of the Philippines." M.S. thesis, Cornell University, 1975.

This study estimates the costs of carrying out agricultural policies to encourage the production of certain nutritious foods and evaluates the effect that the resulting changes in production would have on the nutritional status of the Filipino poor. In doing so, the effects on food prices, incomes, and consumption patterns of specified increases in the production of rice, root crops, pulses, and fish from fresh water ponds are evaluated. From this information, the relative effectiveness of different programs designed to increase calorie and protein consumption is determined. This is then contrasted with the nutritional impact that would accompany the introduction of high-protein rice in the Philippines.

Various studies of food availability and dietary intake in the Philippines are reviewed, and the major nutritional problems of the country are identified. A methodology is developed that incorporates input-output analysis to trace through the input requirements and income-generating effects of different agricultural production programs. A 63-sector input-output model for the Philippines is presented and discussed. Applying the methodology developed here to the analysis of specific agricultural production programs reveals that all approaches would incur very significant support costs. The regional impact varies substantially, and data on the intrafamily distribution of food suggest that little of the increased production would go to children and to pregnant and lactating women, who are the most nutritionally needy members of the population. For these groups, additional programs would be needed if their nutritional status is to be improved.

Kraft, Daryl Frank. "Economics of Agricultural Adjustments to Water Quality Standards in an Irrigated River Basin." Ph.D. thesis, Washington State University, 1975.

Many waste products linked to agricultural production are nonpoint source residuals. This study utilized neoclassical production theory to compare the economic efficiency of abatement programs for point and nonpoint source pollutants from agricultural activity and municipalities in a river basin.

A nonlinear separable programming model was developed to analyze abatement policies designed to reduce the concentration of dissolved nitrogen in the Yakima River of eastern Washington. To reduce nitrogen concentration in the river, farmers were given options of (*a*) adopting more capital-intensive irrigation systems, (*b*) reducing nitrogen fertilizer application, (*c*) reducing cropped acreage, (*d*) changing the crop mix, or (*e*) doing any combination of the former, while municipalities could choose to install a tertiary sewage treatment process. The analysis considered policy alternatives of constraining the instream nitrogen concentration to achieve the desired water quality standard, placing a water users surcharge on irrigation diversions, uniformly reducing rights for water diversion throughout the river basin, or taxing nitrogen fertilizer.

The abatement costs, measured as net social costs, were lowest when resources allocated for crop production and sewage treatment were required to meet a specified level of water quality throughout the waterway. The equilibria derived from limiting the instream concentration of nitrogen are only theoretical optima but do provide a norm to compare the administratively feasible but less efficient water quality programs.

Among the feasible policies, taxing nitrogen fertilizer was the most economically efficient, while a water user surcharge was slightly less costly than water rationing. The differences in abatement costs among the feasible policies were small. The most important factor influencing the cost of abatement was the desired level of abatement rather than the policy instrument utilized to achieve the standard.

Robison, Lindon Joel. "Portfolio Adjustments Under Uncertainty: An Application to Agricultural Financing by Commercial Banks." Ph.D. thesis, Texas A&M University, 1975.

This study uses portfolio theory as the basis for a theoretical model from which theorems relating to bank behavior are deduced. Demand curves for assets are derived and separated into income and substitution effects. The sign of the income effect is related to a decision maker's risk aversion coefficient.

Some of the theoretical results imply that, for the decreasingly risk averse banker, the demand for risky assets will increase with expected returns and decrease with variance. Cross-price effects and covariance effects are shown to depend on whether assets are substitutes or complements in the portfolio. Increasing the deposit feedback effect from loans will increase the demand for loans by the banker. Increasing the liquidity of assets may increase or decrease the banker's holdings of risky assets, but the banker with constant or increasing aversion to risk will decrease his holdings of risky assets.

A quadratic programming model is constructed to demonstrate empirically the application of the theory to a particular bank. Variance and expected returns are calculated, and a basic model solution is found using efficiency criteria discussed in the study. Equilibrium adjustments to changes in selected parameters are then observed and compared to previous model solutions. Finally, policy implications are made based on the theoretical model. Some issues considered relating to the impact on agricultural lending by banks were seasonal borrowing privileges for rural banks from the Federal Reserve System, the development of secondary markets for bank's paper, and increasing deposit costs.

Sexton, Roger Nell. "Determinants of Multiple Job-Holding by Farm Operators." Ph.D. thesis, North Carolina State University, 1975.

The objective of this study was to analyze the factors affecting the amount of labor time supplied to off-farm work by farm operators. A model of multiple job-holding by farm operators was developed to predict the effects of changes in the wage rates received from farm and off-farm jobs on the labor-leisure choices of farm operators engaged in off-farm employment. This analysis was extended using the modern theory of household behavior to take account of the influence of the farm family in determining the amount of time allocated to off-farm work by farm operators.

Off-farm labor supply equations based on the model were estimated using cross-section data from a regional survey of farm operators in the flue-cured tobacco-producing areas of three southern states (Virginia, North Carolina, and South Carolina) as well as from a statewide survey of farm operators in Illinois.

The off-farm supply of farm operators was found to be positively related to the off-farm wage rate received by operators and negatively related to the wage rate received from farm work. The off-farm labor supply of low farm income operators was generally found to be much more responsive to changes in off-farm wage rates than was the off-farm labor supply of farm operators in the data sets taken as a whole. The off-farm wage rate earned by farm wives was not found to have a significant influence on the amount of time supplied to off-farm work by farm operators.

Committee Reports

Report of the President

This has been an eventful and challenging year, both personally and for the AAEA. So many different kinds of activities have been begun or brought to fruition that it is hard to know how to report them briefly. I report first on a number of major events. Then, I shall examine what I believe to be the AAEA's major long-run problem and the actions taken on it this year.

A new *Handbook-Directory* has been prepared this year and will be published as part II of the November 1976 issue of the *Journal*. Since the *Handbook-Directory* normally contains a copy of the Constitution and bylaws, I asked Neil Harl to chair a committee to review our Constitution and bylaws and to make recommendations for changes to the Board. He and his committee have done a first-rate job. I cannot recount the individual changes, most of which incorporate into the bylaws the policy actions of the Executive Board from the last five years. No recommendation for change was made for the Constitution.

After an extensive evaluation of a wide range of publication alternatives, a contract was signed with the University of Minnesota Press for the publication of volume I of the *Review of the Literature of Agricultural Economics since World War II*. This volume will be available in early 1977 and paid-up AAEA members may now order copies at a prepublication discount price. Volume II should also be published in 1977.

The Agricultural Economics Literature Retrieval System, which was sponsored in cooperation with the U.S Department of Agriculture, has been computerized and placed on line and is now accessible by members. Materials on how to use the system have been distributed to all academic departments and governmental agencies, as well as to individual AAEA members. As the capacity of the system increases, it will be an exceedingly valuable research tool for the profession.

The Resident Instruction Committee has continued to work on the development of a new format for student participation in the AAEA annual meetings and for greater emphasis on the problems of teaching and curriculum development. They presented a fine program at the Pennsylvania State University meetings, and I look forward to even further developments by next year. The committee is doing a good job.

The Economics Statistics Committee continues to work on improvement in the data-base of agricultural economics. A workshop on agricultural and world data has been scheduled for early spring in cooperation with the U.S. Department of Agriculture.

The Registry for Agricultural Economists has been financed entirely by a grant from the U.S. Department of Labor. In anticipation of the longer-run decisions that must be made, I appointed a Committee on National Professional Employment Registries, chaired by David Boyne. They are to work with the Employment Services Committee to recommend to the Board some long-run pattern of stable financing and organization for the National Registry.

The directors have begun a systematic evaluation of the annual program format. With the help of several past chairmen of the contributed papers program, the Board directors have reviewed the experience and the policies and rules governing that part of the annual program. Several ideas for change have been discussed, and a committee will be asked to examine some of the problems and to make recommendations for action at the Board's winter meeting. I also appointed this year a committee to evaluate the annual program, chaired by Henry Meenan of the University of Arkansas. The committee's evaluation of the overall format each year will aid the president and Board in planning better programs. If you have any suggestions, get them to the committee.

I put a great deal of effort early this year into reviewing the balance and the distribution of the membership on AAEA committees. One of the primary objectives was to assure that participation in committees is, as the Board has directed, shared widely among the AAEA membership. I found that this was already the case, undoubtably the product of the efforts of other AAEA presidents who have worked hard on the same objective. I have continued in this effort.

Let me report to you on what I think is the primary long-run problem facing the AAEA and on which I spent most of my energies this past year. The problem is exposed in the context of our financial difficulties.

As you well know, we have faced rapidly rising costs, primarily in publication, but in other expenditures as well. The AAEA experienced deficit budgets in 1974 and 1975. By virtue of great effort by the Board and AAEA officers and with the help of members, we appear to be in the black for 1976. However, financial pressures still exist. Obviously we cannot sustain continuing deficits. In such a situation, draconian measures to reduce services would be necessary within a very short period. The more desirable solution lies in two directions—through increasing income directly and through a larger membership.

With a dues increase and page charges instituted last year, I addressed the question of how membership might be increased. The Membership Commit-

tee has concluded that only about half of all agricultural economists are now AAEA members. Why? I believe at least part of the answer lies in the following problem.

Twenty year ago, to be an agricultural economist was automatically to be a member of the AAEA. That was the way in which one identified oneself; it was universally expected. Dues were low, and usually very little thought was given to the decision to join. We have now moved into an era where increasingly individuals ask first, "What is in it for me?" Or, "What do I gain relative to the cost of joining?" In other words, for some reason it has become more of a rational economic decision than a matter of professional obligation, pride, or identification.

Why should this be? I am not sure that I really have all of the answer, but a good part of it must be found in the increasing specialization in what agricultural economists do and value today. We used to do a few closely interrelated things, but now we are fragmented into many more, far narrower specialties that have less immediate commonality. Professional needs have grown equally specialized. At the same time, AAEA services have remained quite general, unspecialized, and very collective in nature—in other words, most of our services are available to members and nonmembers alike! Thus, it becomes more difficult for many to identify closely with the AAEA, and it is not all that surprising that more individuals question whether the value of being a paying member is worth the dues required, especially when you can gain most of the benefits as a nonmember. The same conclusion can be drawn less directly from the increasing number of critical comments about the kind of services that the AAEA renders its members.

The only way to increase membership in the face of this set of problems is to put more systematic effort into recruiting members and to improve the attractiveness of AAEA membership. This we have started to do. We are increasing the energy going into recruiting and are attempting to form a cooperative membership recruiting venture with the other regional agricultural economics associations and the Canadian Agricultural Economic Association. This is only in its earliest stages, but I have great hopes for it.

One way of improving the attractiveness of AAEA membership would be by limiting access to AAEA services to paying AAEA members. The Board and I feel quite strongly that, with dues at higher levels, we have a responsibility to members to see that their resources are used for services to members and not for those looking for a "free lunch." To that end, the following policies governing existing services were approved by the board at its meeting at Penn State: (*a*) the AAEA should, in general, limit committee membership to AAEA members; (*b*) higher registration fees should be charged nonmembers registering to attend the annual meeting; (*c*) the privilege of presenting contributed papers at the annual meeting should be limited to AAEA members, except in special cases in which the condition is waived by the president; (*d*) the privilege of presenting and discussing invited papers and all invited addresses at the annual meeting should be reserved for AAEA members, except in special cases in which the condition is waived by the president. In addition, committees will be debating other questions that may result in additional policy changes. These include consideration of changes in policies governing access to other AAEA activities and services, such as the *Journal* and awards.

The Board is moving as carefully and thoughtfully as possible to transform what have been collective goods, available to all, into selective goods available only to members or available at preferential rates to members. We believe this is only fair to the members to pay the AAEA's bills.

Finally, if we are to increase the value of membership, we must also design new AAEA services to respond to today's more specialized professional interests. In doing this we have to be very careful to maintain the philosophic and organizational integrity that is the nature of our professional association. To pursue this final objective, I have reactivated the Professional Activities Committee under Paul Barkley's leadership to examine our current services and to develop a philosophy and pattern of services that is responsive to members' specialized needs. They are well under way.

I have also asked several other committees to develop recommendations for possible services to members of the AAEA. These include the Extension Affairs Committee and the Industry Advisory Committee. I have also asked the Visiting Lecturer Committee to do the same for the four-year predominantly non-land grant college faculties, where we now have a considerable number of agricultural economists, many of whom are already AAEA members. In another vein, I have appointed an Alternative Publication Committee under the chairmanship of Verner Hurt of Mississippi State University to explore the possibilities and the alternative purposes and design for an eventual new AAEA publication, as recommended by the Smith Committee. Obviously, if our financial situation is not substantially improved over the next few years, a new publication, however modest in scope, would be extremely difficult of attainment.

Over the next three to five years, I am hopeful that what was begun this year will result in a better designed pattern of overall services of greater value to members and a substantial increase in membership.

Respectfully submitted,
James T. Bonnen
President

Resolution

We wish to acknowledge the warm and cordial hospitality shown the AAEA members, their families, and guests on the occasion of the annual meeting held at Penn State University on 15–18 August 1976.

Therefore, be it resolved that the AAEA expresses its sincere gratitude to President John Oswald, Dean James Beattie, College of Agriculture, and to John W. Malone, Jr., chairman of the Department of Agricultural Economics and Rural Sociology, and the faculty, staff, and students, and their families for their hospitality.

All of these, under the able and devoted leadership of Jim Holt, Chairman of the Local Arrangements Committee, as constituted and reported on page 44 of the program, have served us effectively and graciously.

Be it further resolved that a copy of this resolution be sent to President John Oswald, Dr. Malone, Dr. Holt and each member of his committees, and to others at the Penn State University as appropriate.

Report of the Secretary-Treasurer

The AAEA membership for 1975 increased by 191 over 1974 and by 488 over the 1973 low (table 1). Most of the increase this year came from the junior membership, while most of the 1974 increase came from regular members. Considerable effort is being exerted presently to increase membership in all categories.

The 1975 operating statement shows a deficit of $13,845.83 (table 2). Caution must be exercised in examining such statements because extraordinary items often convey normal activity. When the grant received from the U.S. Department of Labor (USDL) to support the activities of the Employment Committee is subtracted from the income and the amount spent by that committee is subtracted from the expense, the actual deficit experienced by the AAEA for 1975 was $15,255.95. The deficit was $2,487.51 in 1973, $22,229.42 in 1974, and $15,255.95 in 1975, making a total deficit of $39,972.88 during the past three years.

One significant point should be made on the income side pertaining to reprints and page charges. Since these activities are interrelated, they were combined for 1975. The miscellaneous income includes a $75 gift, $184.61 for brochures sold, $979.80 as royalties from University Microfilms, and $203.84 in postage collected. On the miscellaneous expense side, the $849.66 includes $81 spent on *Literature Review*, $1.00 for Iowa registration fee, $112.93 for printing of brochures for sale, $24.00 for copyright fees, $564.50 in refunds, and $66.23 in foreign exchange charges not accounted for in reduced income.

The *American Bibliography of Agricultural Economics (ABAE)* ceased publication at the end of 1974. During 1975 refunds were made to those subscribers already paid. All activity is now being directed toward the development of a computerized retrieval system. At this time, it is desirable to make an income-expense summary of this activity (table 3).

Income was from subscriptions, and expenses were the direct cost of preparation of copy and printing. The AAEA assumed all money costs associated with postage, handling, and operating essentially another association, while the U.S. Department of Agriculture assumed the time for preparation of copy. The surplus for 1972 resulted from a $5,000 order by the Agency for International Development to have the *ABAE* sent to all foreign libraries. Considerable quantities of resources are being allocated currently to this activity, and time will tell eventually if they are productive.

In accordance with the policy established in 1973, the income-expense statement for editorial support, as provided by Editor Tomek, is incorporated as a part of this report (table 4).

The balance sheet for the AAEA has deteriorated rapidly over the past three years (table 5). The

Table 1. Number of Members and Subscribers with Comparisons, 1975

Category	1970	1971	1972	1973	1974	1975
Institutional members	39	34	25	20	22	25
Regular members						
U.S.	2,667	2,856	2,802	2,504	2,756	2,779
Foreign	543	486	601	487	480	503
Junior members						
U.S.	494	635	398	316	338	484
Foreign	84	53	38	161	68	66
Corresponding						
U.S.	4	2	—	—	1	2
Foreign	95	100	82	184	198	207
Libraries and business						
U.S.	596	619	647	635	667	670
Foreign	1,031	1,111	1,196	1,168	1,242	1,227
Exchange	3	2	2	3	3	3
Total	5,547	5,898	5,791	5,478	5,775	5,966

Table 2. The 1975 Operating Statement with Comparisons

Item	1973 Actual ($)	1974 Actual ($)	1975 Budget ($)	1975 Actual ($)
Income				
Dues and subscriptions				
Regular members	56,513.62	53,723.13	57,000	55,545.54
Junior members	1,983.84	2,607.92	2,200	4,295.14
Subscriptions	35,141.97	38,430.19	36,000	39,531.64
Corresponding	840.00	930.00	500	1,940.00
Institutional	2,000.00	2,200.00	2,200	2,500.00
ABAE	5,230.87	5,261.76	4,000	3,283.56
Dividends and interest	7,799.37	8,593.25	7,800	9,040.60
Journal sales	4,444.89	5,273.75	4,500	5,714.20
Reprints	3,259.31	4,452.50	3,300	9,575.50
Page charges	—	—	32,000	—
Address labels	835.12	935.40	1,000	557.96
Advertisements	1,065.00	819.64	800	824.80
Student activities	—	—	—	—
Annual meetings	344.67	4,193.34	200	269.80
Employment committee	37,500.00	32,000.00	—	49,500.00
Miscellaneous	5,026.90	16,335.53	3,000	1,443.25
Total	161,985.56	175,756.41	154,500	184,021.99
Expenses				
Journal printing	70,483.40	81,752.64	75,000	79,324.15
Editorial support	15,600.00	23,400.00	17,700	17,700.00
Printing reprints	1,843.76	3,152.71	2,500	2,285.23
Address labels	316.23	—	200	—
Purchase journals	1,028.80	569.64	1,000	323.90
Postage and phone	1,679.09	2,962.58	3,000	3,879.52
Offset supplies and printing	2,932.18	2,385.91	3,000	4,330.22
Annual meeting	1,485.46	4,460.74	2,000	1,712.94
Awards	600.00	1,500.00	1,500	1,500.00
Committees	272.68	357.25	1,200	460.27
Bonds	298.00	149.00	160	149.00
Student activities	842.90	1,129.89	1,200	—
Sec.-treas. asst.	12,851.48	13,874.50	14,300	14,000.83
Sec.-treas. honor	4,000.00	4,000.00	4,000	4,000.00
ABAE	7,729.33	10,655.14	18,000	18,862.22
AAEA grant	5,000.00	—	—	—
Audit	—	200.00	1,000	400.00
Employment committee	12,399.66	49,666.24	—	48,089.88
Miscellaneous	9.76	15,435.83	7,200	849.66
Total	139,372.73	215,652.07	152,960	197,867.82
Balance	22,612.83	−39,895.66	1,540	−13,845.83

1975 statement showed a decrease of $13,845.83 in net worth, but we received $1,410.12 more in grant money than spent, making an actual decrease of $15,255.95.

Since the USDL grant funds were comingled and the AAEA is merely the custodian, it is desirable to point out that the $25,100.34 unspent funds in 1973 reduced our actual net worth to $127,644.74; the $7,434.10 unspent funds in 1974 reduced the actual net worth to $105,415.32; and in 1975 we had $8,844.22 in unspent funds, which decreased our actual net worth to $90,159.37. In three years, our net worth declined by $39,972.88. Our stock is carried on the books at cost.

Table 3. Income-Expense Summary of the *ABAE*—Retrospective Search Activity, 1970–75

	1970	1971	1972	1973	1974	1975	Total
Income ($)	114.00	—	11,478.85	5,230.87	5,261.76	3,283.56	25,369.04
Expense ($)	1,271.00	3,239.65	6,507.70	7,729.33	10,655.14	18,862.22	48,265.04
Balance ($)	−1,157.00	−3,239.65	4,971.15	−2,498.46	−5,393.38	−15,578.66	−22,896.00

Table 4. Operating Statement for Editorial Support, 1975

Income	
AAEA appropriation	$17,700.00
Expenses	
Salaries	
Assistant editor	8,906.48
Secretary	7,400.78
Postage	1,496.67
Copying	239.85
Telephone	676.21
Supplies	517.64
Total expenses	19,237.63
Balance	−1,537.63

Last year an increase in dues was voted, which was necessary to have a breakeven budget. Whether or not our financial position will improve during the next year or two remains in doubt.

Respectfully submitted,
John C. Redman
Secretary-Treasurer

Report of the Audit Committee

The Audit Committee employed the accounting firm of Moore, Wilson, and Smith to examine the financial records of the AAEA of 1975. Their report is as follows.

"We have examined the balance sheet of the American Agricultural Economics Association as of December 31, 1975 and the related statement of receipts and disbursements, fund balance and changes in financial position for the year then ended. Our examination was made in accordance with generally accepted auditing standards, and accordingly included such tests of the accounting records and such other auditing procedures as we considered necessary in the circumstances. In our opinion, the financial statements referred to above present fairly the financial position of the American Agricultural Economics Association as of December 31, 1975, and the results of its operations and the changes in its financial position for the year then ended, in conformity with generally accepted accounting principles applied on a basis consistent with that of the preceding year."

James E. Criswell
Larry D. Jones

Report of the Investment Committee

The portfolio of investments by the AAEA did not change during 1975. The stocks carried on the books at cost of $102,551.99 had a market value of $159,310.125 at the close of the business year, increasing by $22,878.50 from the previous year (table 1). Our investments in stocks yielded $9,040.60 in dividends (table 2).

The AAEA had only one stock—Standard Oil of Indiana, which was worth less at the end of 1975 than at the beginning. However, all stocks took a beating last year. Based on cost, an 8.82% rate of earnings was realized, but when based on market value at the beginning of the year 6.63% was realized.

Respectfully submitted,
John C. Redman

Report of the Finance Committee

This committee was established as a standing AAEA committee by vote of the membership at its annual meeting in August 1975. The responsibilities of the committee were established as follows: (*a*) annually review the AAEA investment portfolio, obtain assistance of professional counsel as deemed appropriate, and make recommendations to the Executive Board; (*b*) annually prepare a proposed budget for the AAEA, including review and projections of income and expenditure commitments, and present the proposal to the Executive Board; (*c*) assist with special assignments as requested by the

Table 5. Balance Sheet 31 December 1975 with Comparisons

Item	1973	1974	1975
Assets			
Cash-bank	$106,217.77	$61,629.15	$63,784.76
Cash-agency act UK	135.99	291.25	1,714.21
Cash-broker	2,123.08	1,896.63	10,937.23
Prepaid expense	—	8,850.00	—
Investments			
Stocks (at cost)	102,551.99	102,551.99	102,551.99
Approximate market value	182,886.125	136,432.625	159,310.125
Total assets (at cost)	210,756.85	175,219.02	178,988.19
Liabilities			
Prepaid membership dues	27,895.67	32,253.50	49,868.50
Accounts payable	30,116.10	30,116.10	30,116.10
Net worth	152,745.08	112,849.42	99,003.59
Total liabilities	210,756.85	175,219.02	178,988.19

Table 1. AAEA Summary of Investments, Year Ending 31 December 1975

	Income		Value	
	1 Jan. 1975	31 Dec. 1975	Cost	Market
Stocks				
On hand, 1 Jan. 1975			$102,551.99	$136,432.625
On hand, 31 Dec. 1975			$102,551.99	$159,310.125
Dividends		$9,040.60		

president and the Executive Board; and (*d*) initiate recommendations for consideration by the AAEA Board that are intended to enhance the AAEA's financial well-being. The secretary-treasurer, John Redman, as the AAEA's principal financial officer, is a critical and key member of this new committee. Two members of the Board and two other AAEA members make up the rest of the five-man committee.

Because of the deficits sustained in 1974 and 1975, the committee has been concerned with the implementation of the new schedule of dues and subscription rates as well as the several enterprises and activities of the AAEA that require annual expenditures. Individual members of the committee have taken responsibility to assist in the evaluation of proposed activities for the AAEA and the expected costs if implemented as enterprises. Special concern during the past year has been given to (*a*) the choice of a publisher for the *Postwar Literature Review*, (*b*) the choice of publishers for the *Journal* at the time of contract renewal in 1976, (*c*) operation of the retrospective search and bibliographic work, and (*d*) grants for the support of the National Professional Employment Registry.

The committee in cooperation with the secretary-treasurer develops basic materials with which the Board can finally establish an annual budget for operations for the coming year at the summer meeting consistent with actions taken on committee recommendations and proposals presented to the Board. The committee intends to give high priority to its budget responsibility and to present a balanced budget for Board approval.

The Finance Committee met in Washington, D.C., on 4 March 1976 to review its responsibilities and establish procedures for assisting the secretary-treasurer and AAEA committees in developing necessary financial data that would allow the Board to make decisions with as much information as possible. During the year the following individuals took special responsibility for keeping informed about these activities: *Journal* and Editorial Service—B. F. Stanton, National Professional Employment Registry—M. Boehlje, Retrospective Search—P. Barry, and Office of Secretary-Treasurer—W. Barr. In addition, Barr and Boehlje assisted in the review of bids for publication of the *Journal*. Stanton met with Babb's committee to evaluate the bids of potential publishers of the *Postwar Literature Review*. President Bonnen has involved appropriate members of the committee whenever budget or important financial issues have been considered throughout the year. Worksheets

Table 2. AAEA Stocks, 31 December 1975

Company[a]	No. of Shares	Original Cost	Dividends 1975	Market Value 31 Dec. 1974	Market Value 31 Dec. 1975
Amer. Cyanamid (A)	250	$ 9,143.43	$ 375.00	$ 5,187.50	$ 6,218.75
Amer. Tel. & Tel. (A+)	288	11,421.11	979.20	12,852.00	14,652.00
Amer. T&T $4CV (AA)	300	16,934.00	1,200.00	14,625.00	16,537.50
Borden (A+)	228	2,162.41	296.40	4,617.00	6,070.50
Chase Manhattan (A+)	93	1,115.09	204.60	2,511.00	2,557.50
Clark Equipment (A−)	600	2,200.67	960.00	13,800.00	15,075.00
Com Edison (A)	232	7,467.14	549.68[b]	5,162.00	7,018.00
Cont Can (A)	225	4,315.38	405.00	5,850.00	6,187.50
Exxon (A+)	153	10,325.36	765.00	9,887.625	13,578.75
Goodyear (A)	500	16,692.50	550.00	6,437.50	10,875.00
Jewell (A)	100	3,875.94	180.00	1,737.50	2,000.00
Nor. Ill. Gas (A)	7	—	13.32	122.50	156.625
Sears Roebuck (A+)	304	1,845.38	562.40	14,668.00	19,608.00
Standard Oil Ind. (A+)	800	7,356.68	1,600.00	34,800.00	34,100.00
Texaco (A+)	200	7,696.90	400.00	4,675.00	4,675.00
Total		102,551.99	9,040.60	136,432.625	159,310.125

[a] Standard and poor ratings shown in parentheses.
[b] Includes $16.08 received from sale of rights.

Table 1. AAEA Consolidated Budgets by Enterprise

Description	1974 Actual	1975 Budget	1975 Actual	1976 Budget	1977 Budget
Income ($)					
Dues and subscriptions	97,891	97,900	103,812	141,725	148,650[a]
Net sales, old *Journals*	4,704	3,500	5,390	3,500	4,500
Page charges, reprints, advertising	—	14,100	9,576	23,500	25,500
Dividends and interest	8,593	7,800	9,041	8,000	10,000
Other	2,271	2,200	2,826	2,200	2,000
Total	113,459	125,500	130,645	178,925	190,650
Enterprise expense ($)					
Publication of *Journal*	103,033	96,800	100,909	102,000	118,000
General expense, sec.-treas.	27,262	36,800	29,413	39,400	39,700
ABAE—retrospective search	5,393	15,000	15,578	15,000	16,000
Postwar Literature Review	—	6,500	—	—[b]	7,500
AAEA *Handbook-Directory*	—	2,000	—	10,000[c]	10,000[c]
IAAE grant	—	—	—	5,000	—
Employment committee	—[d]	—[d]	—[d]	—[d]	—[d]
Total	135,688	157,100	145,900	171,400	191,200
Gain or loss ($)	−22,229	−31,600	−15,255	7,525	−550

[a] Basis for estimate of income for 1977 from dues and subscriptions: regular members—3300 × $25 = $82,500; junior members—500 × $12.50 = $6,250; libraries—1100 × $31.50 = $34,650 and 650 × $35 = $22,750; and institutional members—25 × $100 = $2,500.
[b] Actual commitments for volumes I and II were made in 1976 by special action of the Board, in the amount of $15,000.
[c] Primary payment for the *Directory* will be made in 1977—about $2,000 in 1976.
[d] Employment committee funded by a grant from U.S. Department of Labor. All expenses associated with the National Professional Employment Registry have come from grant funds. The proposed new grant will meet expenses through 30 June 1977.

and initial estimates for the AAEA 1977 budget are attached to this report (tables 1, 2, and 3).

One of the responsibilities of this committee is to make recommendations to the Board with respect to the AAEA's equity and investment holdings. At the March 1976 meeting of the committee, substantial discussion was devoted to the management of the AAEA's assets. The committee agreed to encourage the Board to establish some definite objectives or priorities with respect to the use of its capital. If these objectives were established, then alternative mechanisms to manage the portfolio could be proposed for discussion and approval at the winter meeting of the Board. During 1975 the market value of the AAEA's holdings recovered about $23,000 of the loss in value sustained in the two previous years. A yield of slightly more than 6% on average value was realized.

The capital assets of the AAEA provide an important equity base, which makes it easy for the secretary-treasurer to obtain credit whenever necessary and provides assurance to contractors that AAEA bills will be paid. This underlying objective of maintaining the portfolio should continue

Table 2. Enterprise Budgets for Publication of *Journal*

Description	Approved 1975	Approved 1976	Approved 1977
Expenses ($)			
Printing, 1100 pages	75,000	77,500	85,000
Editorial support	17,700	20,000	20,000
Editorial support, new editor	—	—	10,000
Printing reprints	2,500	2,500	3,000
Postage and labels	1,600	2,000	[a]
Total expenses	96,800	102,000	118,000
Income ($)			
Page charge—$40/page	10,000	22,000	24,000
Sale of reprints	3,300	500	500
Advertising	800	1,000	1,000
Total income	14,100	23,500	25,500
Net enterprise cost ($)	82,700	78,500	92,500

Notes: (*a*) An important part of the expenses associated with the office of the secretary-treasurer is directed to support of *Journal* activities. (*b*) A new editor of the *Journal* will be appointed for the 1978–80 issues. Funds to operate during the transfer of the editor position have been budgeted starting in July 1977. (*c*) Page charges are assumed collected on 600 pages at $40 per page. (*d*) New printing contracts from either Heffernan or Edwards provide similar estimates of costs for an issue of about 1100 pages. (*e*) No income from submission fees is included.
[a] Transferred and combined with postage and supplies item in the enterprise account of the AAEA's secretary-treasurer.

Table 3. Enterprise Budget for General Expenses of AAEA and Office of Secretary-Treasurer

Expense Items	1975 Actual	1975 Budget	1976 Budget	1977 Budget
Secretarial assistance	$14,001	$16,800	$18,500	$16,000
Honorarium, secretary-treasurer	4,000	4,000	4,000	4,000
Postage, phone, supplies	6,610	6,750	7,500	11,000
Awards program	1,500	1,500	1,500	1,500
Travel and committee expense	460	4,400	4,400	1,200
Audit and other expense	2,842	3,350	3,500	6,000
Total	29,413	36,800	39,400	39,700

Notes: (*a*) Resident instruction and other committees of the AAEA have not received funds for meetings or other expenses during the past two years unless specifically authorized by the president or Board. Actual expenditure has been smaller than budgeted. (*b*) Audit and other expense includes the net cost of the annual meeting if any, bonding, the audit, and miscellaneous small items.

to be recognized as important. Management of the capital account of the AAEA could emphasize current income or annual yield, growth of the equity base, emphasis on yield with some growth in the capital base, or emphasis on growth in capital with some minimum annual yield. The committee believes that in the past investment decisions have tended to encourage the holding of quality issues that allow both growth in equity and reasonably high dividends. Only a small number of changes in the portfolio have been made in the past decade. If the Board was to suggest that primary emphasis should be placed on current yield with some growth in the capital base, then some shift toward holding some bonds and out of some of the common stocks might be in order. We recommend that the Board provide the committee with a sense of its emphasis, either toward the third or fourth items above. We can then come to the Board at the winter meeting with more specific information about the costs and associated expectations if this small portfolio is managed by professionals (trust company) or by a committee of AAEA members.

W. Barr
P. Barry
M. Boehlje
J. Redman
B. Stanton, *chairman*

Report of Tellers Committee

Ballots received from the AAEA secretary-treasurer were counted by the Tellers Committee in the manner prescribed by the bylaws to preserve the secrecy of the ballots. The following candidates received the largest number of votes in their respective categories: R. James Hildreth for president-elect, Sylvia Lane for director, and Richard T. Crowder for director.

A. Frank Bordeaux, Jr.
Harry H. Hall

Report of the Editor

The editor devotes considerable time to activities other than reviewing and selecting manuscripts for publication. For example, from 1 July 1975 to 30 June 1976, I wrote thirty letters granting permission to reprint *Journal* material. (It is nice to know that the *Journal* is used.) In addition, I responded to many inquiries and questionnaires about the *Journal* and the AAEA.

The selection of an outstanding article was especially time consuming this year. After four rounds of balloting, we had a tie vote, and Paul Kelley and I agreed, after consulting with the editorial council, to make a coaward to the two articles. Our intent is to continue to give one award per volume, but because of the tie, the award is being shared this year. This approach seemed preferable to using an arbitrary method of breaking the tie.

I continue to doubt the value of the awards program relative to the cost of administering it. However, this is my personal view and not necessarily the view of the editorial council. I will, of course, continue to carry out the wishes of the AAEA to the best of my ability.

Two administrative matters have required my special attention in the past year. One involves the page charge instituted with the August 1975 issue. The page charge is mandatory, but exemptions are granted under certain conditions. Over 75% of the pages in the August 1975 through May 1976 issues that were eligible to pay did honor the charge. The most difficult exemption to administer is the so-called "poverty oath," which permits authors to certify that funds do not exist to honor the charge. The intent of this exemption is to permit students, retired persons, and others without access to institutional or grant funds to publish in the *Journal*. It has been difficult to administer this exemption fairly and consistently, and I have asked the AAEA directors for guidance. On balance, however, I think the policy is working successfully.

A second administrative matter has been participation in the ad hoc committee on the renewal of the *Journal's* printing contract. This committee,

chaired by Wallace Barr, has made a separate report to the directors, but I want to mention the sharply rising costs of publishing the *Journal*. The 1,032 pages in the 1975 volume cost about $75,000 to print, and the 1976 volume will be at least 5% higher. The 1977 volume will probably cost more than the 1976 volume. Thus, the cost of printing a 1,000 to 1,100 page volume in 1977 may be about $85,000. We will likely reduce the quality of the cover, the paper, and the binding of the *Journal* to make some modest savings in costs. Little more can be done to reduce costs aside from major modifications such as reducing the pages published. The directors may well have to face some difficult decisions about the future nature of the *Journal* in the years ahead.

Two hundred sixty-three manuscripts were submitted from July 1975 through June 1976, a decrease of sixty-nine from last year (table 1). The current level of submissions is similar to the recent norm, and last year's experience must be viewed as an exceptionally large number of submissions. I am surprised, however, that an association of about 4,000 members cannot generate a larger volume of submissions. In addition, the breadth of subjects covered by submissions appear to be smaller than the breadth of interests of the AAEA members.

I think, however, that our publication record indicates an openness to manuscripts in all aspects of agricultural economics. Four papers this year deal directly with undergraduate teaching. These are papers that have gone through the review process and do not include invited proceedings papers. In addition, I would hope that other papers are useful to teachers as well as to researchers. The *Journal* contains articles on contemporary policy issues, such as buffer stocks, and also essays with no mathematics as well as methodological pieces.

Ninety-two articles and notes were published in 1976, 35% of the manuscripts submitted (table 1). This acceptance rate is within the range of experience of the past eight years. The *Journal* does not have a backlog of manuscripts awaiting publication,

Table 1. New Submissions, Manuscripts Accepted, and Acceptance Rate, 1966/67–1975/76

Year	Number of New Submissions[a]	Manuscripts Accepted for Publication	Acceptance Rate (%)
1966–67	195	96	49
1967–68	212	100	47
1968–69	268	105	39
1969–70	249	95	38
1970–71	250	96	38
1971–72	264	96	36
1972–73	263	90	34
1973–74	285	98	34
1974–75	332	91	27
1975–76	263	92	35

[a] Excludes proceedings papers and book reviews.

Table 2. Number of Articles, Notes, and Proceedings Papers Published, 1972–76

	1972	1973	1974	1975	1976
Articles	30	22	25	48	47
Notes	66[a]	68[a]	73[a]	43	45
Proceedings	60	51	58	56	43
Total	156	141	156	147	135

[a] Short articles and communications combined.

and once accepted, papers are promptly published. A typical lag from date of initial submission to date of publication is one year. Manuscript review usually requires about two months, and the publication process requires about four months. The remainder of the lag is related to the time spent by authors on revisions.

In addition to refereed manuscripts, the editor's office handled forty-three proceedings papers (table 2). Our main role is to prepare the manuscripts for the printer. Last year my associates and I read each paper with some care and undertook a more extensive editing of these papers than has been customary. Our intent was to have a somewhat more uniform product than in the past. We expect to continue this practice.

I have invited two papers that will appear in 1977. One will compare organic farms with traditional Corn Belt farms. The objective of this invitation is to stimulate research, thought, and comment on this controversial topic. A second invited paper will review the literature on sequential estimators in econometrics. Most of the empirical econometrics that we publish involve data dredging, and many authors do not appear to understand the statistical implications of their procedures. Thus, the objective of the second invitation is to survey the literature and to increase the understanding of our profession about the implications of modifying models in the light of a set of preliminary results.

The *Journal* can be published only with the assistance and cooperation of a number of persons. Carol Burns, the assistant editor in 1975, resigned to continue a graduate program in English literature. Carol made significant contributions to the current style of the *Journal*. As we wish Carol well in her graduate studies, we welcome Nancy Larrabee as the new assistant editor. The editorial council continues to assist with reviews, to comment on policy as well as to select an outstanding article. In addition to the council members, 388 individuals assisted with reviews; the number of persons reviewing manuscripts has grown even though the number of submissions has declined. I am pleased to recognize the important contribution of the reviewers by publishing their names in table 3.

William G. Tomek
Editor

Table 3. Reviewers, June 1975 to June 1976

Richard M. Adams
John Adrian
P. G. Allen
Vernon Allen
Jock R. Anderson
Raymond L. Anderson
William L. Arends
Roger C. Avery
Harry W. Ayer
Emerson M. Babb
Robert Bain
C. B. Baker
Malcolm D. Bale
Paul W. Barkley
Richard L. Barrows
Peter J. Barry
George Beckford
Jere R. Behrman
Enoch Bell
Carlos A. Benito
Arlo W. Biere
Hans P. Binswanger
Gordon E. Bivens
R. D. Blair
Brian F. Blake
Leroy L. Blakeslee
Leo V. Blakley
Michael Boehlje
Jean-Marc Boussard
Lawrence J. Brainard
George E. Brandow
Maury Bredahl
Harold F. Breimyer
J. L. Bridge
George L. Brinkman
S. M. Brock
Ray F. Brokken
Daniel W. Bromley
John R. Brooker
R. Charles Brooks
Ralph M. Brooks
David W. Brown
William G. Brown
W. Keith Bryant
William R. Bryant
J. Bruce Bullock
Oscar R. Burt
Rueben C. Buse
Walter Butcher
Boyd Buxton
Keith Campbell
W. B. Candler
Thomas A. Carlin
Daryl Carlson
Gerald A. Carlson
Anne P. Carter
Kenneth L. Casavant
Emery N. Castle
William Cathcart
Wen S. Chern
Dennis Chinn
Lee Christensen
M. Gardner Clark
Willard W. Cochrane
Norman R. Collins
Robert I. Coltrane
Dale K. Colyer
Frank S. Conklin
George J. Conneman
Neil R. Cook
Thomas F. Cooley
Sam M. Cordes
Richard J. Crom
William I. Cromarty
James A. Crutchfield
Ronald G. Cummings
Andrew G. Cuthbertson
Dale C. Dahl
Dana G. Dalrymple
Leroy Davis
John C. Day
Richard H. Day
David L. Debertin
Gerald A. Doeksen
Otto C. Doering, III
John P. Doll
Ronald Dorf
Peter P. Dorner
Folke Dovring
W. David Downey
H. Evan Drummond
K. William Easter
Matthew Edel
Clark Edwards
Alvin C. Egbert
Vernon Eidman
Joachim Elterich
Robert D. Emerson
Robert F. Engle
Donald J. Epp
Gordon Erlandson
M. Dean Ethridge
Robert Evenson
Walter P. Falcon
R. W. Farebrother
John N. Ferris
Robert Finley
Loyd K. Fischer
W. L. Fishel
D. Lynn Forster
John H. Foster
John R. Franzmann
J. W. Freebairn
Ben C. French
Charles French
R. J. Freund
Conrad F. Fritsch
Hazen F. Gale
B. Delworth Gardner
Bruce L. Gardner
Charles B. Garrison
Peter V. Garrod
P. S. George
Paul H. Gessaman
Animesh Ghoshal
Micha Gisser
E. Bruce Godfrey
Robert S. Golden
Frank M. Goode
John W. Goodwin
Lee Gray
Roger W. Gray
Richard Green
Davydd J. Greenwood
R. Clyde Greer
G. Robinson Gregory
Wade Gregory
Wade L. Griffin
F. H. Gruen
David K. Guilkey
Russell L. Gum
Walter Haessel
Harold Halcrow
Darwin C. Hall
Milton C. Hallberg
Albert N. Halter
Jerome W. Hammond
Timothy M. Hammonds
Charles R. Handy
Bent Hansen
David E. Hansen
David H. Harrington
Duane G. Harris
Stephen B. Harsh
Joseph Havlicek
Michael Hay
Yujiro Hayami
Peter B. R. Hazell
J. C. Headley
D. H. Hedley
G. W. Hedlund
Theodor H. Heidhues
Dale M. Heien
Richard G. Heifner
Peter G. Helmberger
John Helmuth
Robert Herdt
William Mcd. Herr
Robert O. Herrmann
L. Dean Hiebert
H. N. Higinbotham
R. James Hildreth
Lowell D. Hill
Jimmye S. Hillman
Glenn C. Himes
Irving J. Hoch
George H. Hoffman
David W. Holland
Gerald L. Horner
Douglas Horton
James P. Houck
Verne W. House
Richard Howitt
Darrell L. Hueth
Wallace E. Huffman
John M. Huie
Leroy Hushak
Yuji Ijiri
Craig L. Infanger
Geoffrey Jackson
Robert E. Jacobson
J. Dean Jansma
Harald R. Jensen
Edward Jesse
Glenn L. Johnson
Paul R. Johnson
Stanley R. Johnson
Bruce F. Johnston

Table 3. (Continued)

Richard S. Johnston	Lester H. Myers	Jerry A. Sharples
Warren E. Johnston	W. M. Myers	Charles Shaw
Larry Jones	James J. Naive	C. Richard Shumway
Lonnie L. Jones	Glenn L. Nelson	Richard L. Simmons
George Judge	James R. Nelson	Richard W. Simunek
Richard E. Just	Kenneth E. Nelson	Robert Sinclair
Robert J. Kalter	Michael Nelson	J. A. Sinden
Don Kanel	Paul E. Nelson, Jr.	Melvin D. Skold
Earl W. Kehrberg	Gerald W. Nolte	Leslie Small
John O. S. Kennedy	Richard B. Norgaard	Dennis K. Smith
Nabil Khaldi	Ronald M. North	V. Kerry Smith
Robert W. Kilpatrick	C. W. O'Connor	Steven T. Sonka
Yoav Kislev	J. Frank O'Connor	Vernon Sorenson
Rodney C. Kite	Quirino Paris	Robert G. F. Spitze
Ronald D. Knutson	William L. Park	Anthony P. Stemberger
K. R. Krause	Loren Parks	Joe B. Stevens
Joe Kropf	D. W. Parvin, Jr.	Robert D. Stevens
George W. Ladd	B. Peter Pashigian	Thomas H. Stevens
Max R. Langham	Anne E. Peck	Laurence D. Stifel
Olaf F. Larson	J. B. Penn	Thomas F. Stinson
Lawrence J. Lau	Michael Perelman	Abraham Subotnik
T. C. Lee	R. K. Perrin	W. B. Sundquist
Uma Lele	Willis L. Peterson	Jon G. Sutinen
Raymond M. Leuthold	T. P. Phillips	Takashi Takayama
Steve Levine	Ronald R. Piggott	H. Talpaz
Lawrence W. Libby	Per Pinstrup-Andersen	Robert W. Taylor
Samuel H. Logan	A. A. Powell	William C. Thiesenhusen
Burl Long	Anthony A. Prato	Robert L. Thompson
William Lord	Lee E. Preston	Stanley Thompson
Bruce McCarl	David W. Price	C. Peter Timmer
Kenneth E. McConnell	Glenn C. Pulver	William D. Toussaint
Russell F. McDonald	L. C. Quance	Raphael Trifon
James W. McFarland	Hans D. Radtke	Peter Tryfos
John P. McInerney	Alan Randall	Luther G. Tweeten
Melville L. McMillan	Norman Rask	Fred H. Tyner
Robert J. Mackay	Philip Raup	Edward W. Tyrchniewicz
J. A. MacMillan	Daryll E. Ray	Edward J. Vander Velde
J. Patrick Madden	Gerald Rector	Michele M. Veeman
Alden C. Manchester	John C. Redman	John J. Waelti
Lester V. Manderscheid	Uwe E. Reinhardt	Arley D. Waldo
Jitendar S. Mann	Shlomo Reutlinger	Rodney Walker
Harry P. Mapp	Clark W. Reynolds	Richard G. Walsh
Richard T. Marasco	John B. Riley	Forrest Walters
John M. Marsh	Gordon Rose	Ronald W. Ward
Larry J. Martin	James Roumasset	Philip F. Warnken
Lee R. Martin	Blair E. Rourke	Leonard Waverman
Neil Martin	William Ruble	Leon Wegge
William E. Martin	Robert W. Rudd	Donald A. West
Loys S. Mather	Abdullah A. Saleh	Fred White
Gene A. Mathia	Michael S. Salkin	Norman K. Whittlesey
Joseph C. Meisner	William A. Schaffer	Willard F. Williams
Charles E. Metcalf	W. Harry Schaffer	Cleve E. Willis
Richard L. Meyer	W. Neill Schaller	Walter J. Wills
Edgar L. Michalson	John R. Schmidt	Ewen M. Wilson
Russell Middleton	Andrew Schmitz	Michael E. Wirth
Thomas A. Miller	L. D. Schnake	Robert H. Wisner
Marvin P. Miracle	Dean F. Schreiner	Jerome M. Wolgin
C. V. Moore	Ronald A. Schrimper	Roger Woodworth
Theodore F. Moriak	G. Edward Schuh	Craig C. Wu
Timothy D. Mount	Michael Schultheis	Mitoshi Yamaguchi
Mohinder S. Mudahar	John T. Scott, Jr.	Robert Young
W. F. Mueller	Benjamin Sexauer	Carlos A. Zulberti
Yair Mundlak	Leonard Shabman	
Wesley Musser	Ronald E. Shaffer	

Note: Editorial Council members are listed inside the front cover.

Report of the *Handbook-Directory* Committee

Energies of the *Handbook-Directory* Committee have been devoted to implementing the publication of the *Handbook-Directory* in November 1976. All deadlines in the schedules have been met and we expect to meet the 1 November 1976 publication date.

The remaining decision to make is the price of the *Handbook-Directory*. Formerly, the price for nonmembers was the same as the annual membership dues; thus, the price of the last *Handbook-Directory* was $15. If we follow this same policy, the price of this issue would be $25 to nonmembers.

Only 100 copies of the last *Handbook-Directory* were sold at $15 to nonmembers. We cannot foresee any precipitous increase in the nonmember demand for this publication. The marginal cost of copies for this purpose would be minimal. We feel that a price of $25 per copy would be prohibitive and recommend the price of $15 to nonmembers. However, we would like to have the thinking of the Board on the two alternatives.

We appreciate the input of the Board and the membership in the development of this publication.

Respectively submitted,
Joseph Ackerman (deceased)
Emanuel Melichar
John Redman
Howard F. Robinson, *chairman*

Report of the *Postwar Literature Review* Committee

All seven of the surveys to be included in volume I are in the hands of the publisher, the University of Minnesota Press. As of 1 August copy editing on the first six surveys had been completed and typesetting was under way on the first three. The table of contents for volume I will look like this:

Survey

I. "Farm Management—Production Economics" by Harald R. Jensen, University of Minnesota (125 pp. of text, 36 pp. of references).

II. "The Analysis of Production Efficiency in Agricultural Marketing—Models, Methods, and Progress" by Ben C. French, University of California, Davis (109 pp. + 98 pp.).

III. "Policy for Commercial Agriculture: A Review of Literature" by G. E. Brandow, Pennsylvania State University (118 pp. + 23 pp.).

IV. "Postwar Policies Relating to Trade in Agricultural Products" by D. Gale Johnson, University of Chicago (35 pp. + 28 pp.).

V. "Agricultural Price Analysis and Outlook: A Review of Literature" by William G. Tomek and Kenneth L. Robinson, Cornell University (102 pp. + 41 pp.).

VI. "Agricultural Finance and Capital Markets—A Review of Literature since World War II" by John R. Brake, Michigan State University, and Emanuel Melichar, Board of Governors of the Federal Reserve System (102 pp. + 32 pp.).

VII. "Technical Change in Agriculture" by Willis Peterson, University of Minnesota, and Yujiro Hayami, Tokyo Metropolitan University (65 pp. + 27 pp.).

All of the surveys that will go into volume II have been received from the authors and have been placed in the hands of the publisher. The table of contents for volume II will look like this:

Introduction by George Judge, University of Illinois.

VIII. "On Estimating the Parameters of Economic Relations: A Review" by George G. Judge, University of Illinois (about 38 pp. + 12 pp.).

Commentary on VIII by Richard J. Foote, Texas Technological University (5 pp. + 2 pp.).

IXA. "On Economic Optimization: A Nontechnical Survey" by Richard H. Day, University of Wisconsin (40 pp. of text, 22 pp. of figures, notes, and references).

IXB. "Optimization Models in Agricultural and Resource Economics" by Richard H. Day and Edward Sparlin, University of Wisconsin (28 pp. + 36 pp.).

IXC. "Agricultural Production Functions from Experimental Data" by Roger C. Woodworth, Tennessee Valley Authority (26 pp. + 14 pp.).

X. "Systems Analysis and Simulations: A Survey of Applications in Agricultural Economics" by S. R. Johnson, University of Missouri, and Gordon C. Rausser, Iowa State University (124 pp. + 68 pp.).

XI. "Developments in Agricultural Economic Data" by M. L. Upchurch, University of Florida (136 pp. + 19 pp.).

The surveys for volume III are further from completion. The status of these surveys is approximately as follows.

XII. "Philosophic Foundations of Agricultural Economic Thought" by Glenn Johnson, Michigan State University (about 75 pp.); Johnson expects to have a first draft ready by 15 September 1976.

XIII. "Organization and Performance of Agricultural Markets" by Peter Helmberger, Gerald R. Campbell, and William D. Dobson, University of Wisconsin

(about 100 pp.); Helmberger and his colleagues expect to have a first draft by the end of summer 1976.

XIV. "Natural Resource Economics" by Emery N. Castle, Oregon State University and Resources for the Future; Maurice M. Kelso, University of Arizona; and Herbert H. Stoevener and Joe B. Stevens, Oregon State University (about 125 pp.); the authors are in the process of preparing the final draft, which is anticipated this fall.

XV. "Economics of Rural Poverty" by D. Lee Bawden, University of Wisconsin and Urban Institute, and W. Keith Bryant, Cornell University (about 100 pp.); a first draft has been promised by the end of 1976.

XVI. "Rural People, Communities, and Regions"; leadership for this set of surveys is being provided by George S. Tolley, University of Chicago.

Introduction by George S. Tolley, University of Chicago (about 12 pp.); will be prepared when three principal surveys are brought to final form.

XVIA. "Economic Bases for Growth" by Clark Edwards, Economic Research Service (about 81 pp. + 27 pp.); Edwards's draft is in the hands of committee reviewers, after which it will be prepared in final draft.

XVIB. "Rural Development: Problems and Prospects" by Dean Jansma, Hays Gamble, Patrick Madden, and Rex Warland, Pennsylvania State University (about 92 pp. + 26 pp.); a draft of this draft is also in the hands of committee reviewers, after which it will be prepared in final draft.

XVIC. "Population Distribution: Migration and Settlement Patterns" by Marion Clawson, Resources for the Future (about 18 pp. + 7 pp.); Clawson's draft is in the hands of committee reviewers, leading to a final draft.

XVII. "Agriculture in Economic Development"; leadership for this group of surveys is being provided by Carl Eicher, Michigan State University, John Mellor, Cornell University, and G. Edward Schuh, Purdue University.

XVIIA. "Africa" by Carl Eicher (about 75 pp.); first draft promised by the end of 1976.

XVIIB. "Asia" by John Mellor (about 75 pp.); first draft promised by the end of 1976.

XVIIC. "Latin America" by G. Edward Schuh (about 75 pp.); first draft promised by the end of 1976.

The title of survey XVI has not been finally decided upon.

The title of the three volume set is to be *A Survey of Agricultural Economics Literature*. The subtitle of volume I will be "Traditional Fields of Agricultural Economics, 1940s to 1970s," edited by Lee R. Martin; that of volume II will be "Quantitative Methods in Agricultural Economics, 1940s to 1970s," edited by George G. Judge, University of Illinois, Richard H. Day, University of Wisconsin, S. R. Johnson, University of Missouri, Gordon C. Rausser, Iowa State University, and Lee R. Martin, University of Minnesota; and that of volume III will be something like "Development, Welfare, and Natural Resources in Agriculture," edited by Lee R. Martin. The title pages will include the information that the set was published for the AAEA by the University of Minnesota Press.

Report of Committee on Publication of *Postwar Literature Review*

The committee considered two methods of publishing the first volume of the *Review*: use the services of a book publisher or have the AAEA act as its own publisher. Invitations to submit proposals were sent to forty-three publishers and ten proposals were received. Invitations to submit bids on printing were sent to twelve printers and ten proposals were received. A detailed analysis of these proposals was made, and the committee met 15 December 1975 to finalize recommendations to the Board. Recommendations about alternative methods of publication were presented to the Board at its December meeting. The Board instructed the committee to negotiate an agreement for publication of volume I with the University of Minnesota Press. An agreement was signed in April 1976, and volume I is scheduled for distribution in early 1977.

The University of Minnesota Press has accepted volume II of the *Review* for publication. The committee recommended that the Board enter into this agreement, which is almost identical to that for volume I.

Emerson M. Babb, *chairman*

Report of the Awards Committee

The central objective of the awards program of the AAEA is to encourage the achievement of excellence for a broad range of professional activities of agricultural economists. The process of selecting award winners might have limited purpose if it did not provide a means for communicating to the total membership standards of professional excellence of achievement by a large proportion of the AAEA. Furthermore, the awards activity provides a means of communicating to other professional groups our standards of achievement not only in terms of rigor and quality but their social relevance in today's world.

If these are among the more fundamental reasons for the existence of the AAEA awards activity, then it follows that (*a*) continuing effort needs to be directed toward goal definition and processes that result in wide acceptance of the purpose and worth of the awards activity; (*b*) there must be wide participation in terms of entries; (*c*) selection processes must be such that truly outstanding winners are selected (those who do not achieve final winner status must have some indication of their relative rank in the awards activity, i.e., to make it worthwhile to "run the race"); and (*d*) there must be a continuing high level of professional performance by the Awards Committee in carrying out the awards activity and feedback to the total membership.

The AAEA is a complex institution. Leadership needs to constantly search out methods that promote real incentives and mechanisms for participation by a broad base of the membership.

There appears to be a substantial belief among smaller departments in smaller universities that they do not have a chance of winning in national competition. Hence, they do not enter. My evidence is that our national leadership is deeply concerned about this type of problem and has made every possible effort to select the Awards Committee from as broad a representation as possible with regard to geographic area, size of department, and degree-granting institutions. If the awards program is to continue to move ahead as the committee thinks it should and is, membership must participate more fully. There are some encouraging signs in this direction.

The M.S. and Ph.D. programs appear to be the most popular in terms of number of entries. Only about one-third to one-half as many entries are submitted for teaching and extension activities as for the above degree program. For the program to offer something to all experience and interest levels in the association, greater participation emphasis in areas other than the M.S. and Ph.D. categories must be achieved.

The committee strongly supports the awards program and urges that it be continued subject to certain modifications. Committee chairmen have carefully evaluated the activities of their representative award area during the past year. Their recommendations have been forwarded to President Bonnen, President-elect Farrell, and the 1977 general chairman of the awards program, Gordon Ball.

I wish to personally express my thanks to each committee member for the dedication and effort they exerted in making the 1976 awards program a meaningful and successful activity for the AAEA.

The AAEA awards winners for 1976 follow.

Distinguished Extension Program

Less than ten years. **Harold D. Guither,** professor, University of Illinois, agricultural policy.

Ten or more years. **Edward Uvacek, Jr.,** associate professor, Texas A&M University, livestock marketing.

Distinguished Undergraduate Teaching

Less than ten years. **William D. Dobson,** associate professor, University of Wisconsin, agricultural marketing.

Ten or more years. **Neil E. Harl,** professor, Iowa State University, resource economics.

Outstanding Master's Degree Program

Hung Yu Hu. "Analysis of Factors Affecting Supply of Off-Farm Labor among Taiwanese Farmers." Ohio State University (adviser: Donald W. Larson).

Renato G. Pieri. "The North American-Japanese Pork Industries: An Economic Analysis." University of Guelph (adviser: K. D. Meilke).

John M. Staatz. "The Economic and Nutritional Impact of Changes in Agricultural Production Patterns: The Case of the Philippines." Cornell University (adviser: Daniel Sisler).

Outstanding Doctoral Degree Program

Lindon Joel Robison. "Portfolio Adjustments Under Uncertainty: An Application to Agricultural Financing." Texas A&M University (adviser: Peter J. Barry).

Roger N. Sexton. "Determinants of Multiple Job Holding by Farm Operators." North Carolina State University (adviser: Dale M. Hoover).

Daryl Frank Kraft. "Economics of Agricultural Adjustments to Water Quality Standards in an Irrigated River Basin." Washington State University (adviser: Norman Whittlesey).

Quality of Research Discovery

Gordon C. Rausser and Richard Howitt. "Stochastic Control of Environmental Externalities." *Annals of Economic and Social Measurement.* April 1975.

David E. Kenyon and Samuel Evans. *Short-term Soybean Acreage Projection Model Including Price and Policy Impacts.* Virginia Polytechnic Institute and State University Res. Div. Bull. 106, Sept. 1975.

Quality of Communication

R. James Donald and Levi A. Powell. *The Food and Fiber System—How It Works.* USDA ERS. Agr. Inform. Bull. 383, March 1975.

Michael Boehlje and Larry Trede. *Financing the Iowa Livestock Producers.* Iowa State University in cooperation with Iowa Development Commission, 1975.

Publication of Enduring Quality

Earl O. Heady. *Economics of Agricultural Production and Resource Use.* Englewood Cliffs, N.J.: Prentice-Hall, 1952.

Outstanding Journal Article

Masakatsu Akino and Yujiro Hayami. "Efficiency and Equity in Public Research: Rice Breeding in Japan's Economic Development." *Amer. J. Agr. Econ.* 57 (1975):1–10.
Bruce L. Gardner. "The Farm-Retail Price Spread in a Competitive Food Industry." *Amer. J. Agr. Econ.* 57 (1975):399–409.

Browning Award

The winner will be announced at the annual meetings of the American Society of Agronomy, 28 Nov.–3 Dec. 1976, Houston, Texas.

Report of the Bibliographic-Retrospective Search Committee

A memorandum of understanding between the AAEA and the National Agricultural Library (NAL), Economic Research Service, and Statistical Reporting Service of the U.S. Department of Agriculture was signed in October 1975. The memorandum of understanding confirms the interest and support that each party will contribute in making operational a computerized retrieval system of relevant literature by agricultural economists, other researchers, and administrators.

Last year's recommendations of this committee and the Gardner committee and the subsequent actions by the Board in August 1975 changed the "charge" of the committee. Consequently, this committee met in early December 1975 to consider ways of fulfilling its new responsibilities and to prepare a preliminary report for the Board's consideration at the winter meetings. All members of the committee participated in the meeting, as did Isabel Jenkins, director, American Agricultural Economics Documentation Center (AAEDC).

The two major topics considered at the committee meeting were how to increase participation of the membership in submitting documents to the AAEDC and how to best promote the use of the retrospective search routine by members of the association.

A report of the committee was submitted to the Board at the winter meetings in Dallas. The report is summarized as follows. The committee discussed the Board's approval to publish an author-title list in the *Journal* to publicize documents received by the AAEDC. The annual cost was conservatively estimated to be $1,600. Although such a listing could be a most effective means of promoting the retrospective search system, the committee recommended that publication in the *Journal* be deferred. It was felt that other alternatives for promoting the retrospective search system would be more cost effective. Alternatives suggested included (*a*) a descriptive brochure, (*b*) a letter to the department heads, (*c*) an annual report by the AAEDC, (*d*) a one-page announcement in the *Journal* promoting the AAEDC and the retrospective search system, and (*e*) a demonstration of the system at the next annual meeting.

The report was well received by the Board. Alternatives (*a*) and (*b*) have been effected. In addition, a special newsletter was sent out with the president's newsletter in April, announcing that the "*American Bibliography of Agricultural Economics* Goes On-Line" in late April. Alternatives (*c*), (*d*), and (*e*) were also given strong support by the Board. A report from the AAEDC is to be prepared on an annual basis, the editor of the *Journal* gave support to a page announcement in the *Journal,* and arrangements are underway for a demonstration of the system at the annual meetings.

The information base of the AAEDC was added to the CAIN System maintained by the NAL. There are almost thirty departments of agricultural economics whose university libraries currently have CAIN on-line operations. Thus, members of these departments have direct access to the AAEDC file through terminals in their libraries. Other departments or firms will need to contact one of the two commercial vendors who offer access and training in the use of on-line terminals and search routines.

It will take some effort on the part of each department to assess the system. The committee should follow through on this and provide any information that will be helpful to individual departments and potential users of the system. Perhaps the experiences of some of the earlier users can be documented so that it will be helpful for other potential users.

The committee unanimously decided that it would be helpful to assign a committee member to be the primary contact in each of five geographic areas. The committee member would be responsible for maintaining liaison with the cooperators and department heads in the assigned areas. The geographic assignments were as follows: (*a*) Northeast (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, West Virginia, Delaware, and Maryland)—Ray C. Smith; (*b*) Southeast (Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Arkansas, Alabama, Mississippi, and Louisiana)—J. Edwin Faris; (*c*) Great Plains (North Dakota, South Dakota, Wyoming, Colorado, Montana, Nebraska, Kansas, Oklahoma, Texas, and New Mexico)—Ivan W. Schmedemann; (*d*) Midwest (Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota,

Missouri, and Iowa)—John T. Scott; (*e*) Far West (Washington, Oregon, California, Utah, Nevada, Idaho, Arizona, Alaska, and Hawaii)—Marvin G. Julius; (*f*) Canada and other countries—Isabel Jenkins; and (*g*) ERS and other government agencies—Allan S. Johnson and Richard C. McArdle.

The committee suggests that it would be appropriate to have a Canadian on the committee. Also, future appointments to the committee might be partly based on the above listed geographical areas.

The committee members have not been very active this year in terms of their geographical responsibilities. It was necessary to have the retrospective search routine fully operational before making individual contacts. Too often a computerized system has not lived up to its expectations in terms of the time it was operational. The committee members will follow up on the letter recently sent to all department heads and cooperators.

Another area that was given consideration by the committee during the year was possible cooperation with other organizations having literature-retrieval systems. A subcommittee investigated several systems: AGRIS, sponsored by the Food and Agricultural Organization; Smithsonian Science Information Exchange (SSIE), originally sponsored by the Smithsonian Institute; and the Psychological Abstract File, sponsored by the American Psychological Association. Basically, each is oriented toward other areas than agricultural economics. AGRIS has a cooperative agreement with NAL. However, NAL has been unable, as of this time, to get any information off the AGRIS tapes. SSIE obtains their information from NAL but is biologically oriented. The subcommittee feels that now is not the time to spend much effort in pushing cooperation with others concerning information-retrieval systems. The system being developed by our profession is far superior for the needs of agricultural economists than the other systems. It is more complete, and the cost of searching the files would undoubtedly be considerably less than using a combined file. Perhaps at a later date cooperation with AGRIS should be reconsidered. However, we would be giving much more than we would be receiving.

Several possibilities for having the AAEDC files published have presented themselves during the year. The Oryx Press, current publisher of the *Bibliography of Agriculture*, is one possibility. These possibilities should be further investigated next year as they may provide a means of obtaining a hard copy of documents submitted to the AAEDC at no cost to the AAEA.

The committee briefly discussed the possibility of microfiche as an alternative to publishing the *ABAE*. The Committee felt that it was not a very good alternative and would not really help promote the use of the retrospective-search system.

J. Edwin Faris

Report of Agricultural Statistics Committee of Federal Statistics Users Conference

The FSUC Agricultural Statistics Committee was reactivated in late 1975. A new committee was formed with a representation from many areas of agriculture that utilize federal statistics. A meeting of the newly formed committee was held in Washington, D.C., on 11 November 1975 for the primary purpose of establishing objectives and determining the general direction that the committee should follow.

The objectives of the Agricultural Statistics Committee are: (*a*) to aid in maintaining and improving quality and timeliness of federal statistics related to agriculture, (*b*) to improve communications between users and producers of federal statistics, (*c*) to increase awareness of both short- and long-term changes and additions to federal statistics necessary to meet requirements of a changing agriculture, (*d*) to convey to producers of agricultural statistics the requirements of statistical users and to prioritize those requirements, (*e*) to provide information and make appropriate recommendations to FSUC staff and Board of Trustees concerning matters of consequence related to agricultural statistics, (*f*) to assist FSUC staff in presenting a statement relative to federal budget requests for statistical programs to respective subcommittees on appropriations, and (*g*) to maintain liaison with other committees that have an interest in maintaining and improving the quality and timeliness of federal statistics related to agriculture.

The methods of operation were established. The meeting schedule is one meeting each year to coincide with the FSUC annual meeting, and special meetings may be called as required by the committee. The FSUC staff will assist and participate in coordinating the activities of the committee. Committee membership shall be limited to members of FSUC member organizations and to those interested and involved in agricultural statistics. Subcommittees may be appointed by the chairman, as required.

The intention of the committee is to provide a positive and progressive influence in the area of agricultural statistics. This intent was expressed at a February 1976 meeting in which the committee met in Washington, D.C., with key producers and users of federal statistics. The objectives of the committee were discussed, and the key producers of federal statistics outlined their programs and priorities.

The committee's offer to assist in the evaluation of federal data revisions, additions, and deletions was well received. This offer is being carried out with suggestions offered as the need arises.

There are a number of current activities in the federal government focusing attention upon agricultural statistics such as congressional hearings on the definition of "a farm" and House and Senate

bills on the transfer of the *Census of Agriculture* from the Department of Commerce to the Department of Agriculture. These are being monitored by FSUC and the committee, and appropriate action will be taken as indicated. Plans are being made for committee participation in the proposed Agricultural and Rural Data Workshop to be sponsored by ERS, SRS, AMS, and the AAEA Economics Statistics Committee.

Suggestions for furthering the objectives of this committee will be appreciated.

Norman M. Coats, *chairman*

Report of the Economic Statistics Committee

The most significant accomplishment of the committee was a review and evaluation of food price data by a joint task force of the AAEA Economic Statistics Committee and the Economic Research Service, U.S. Department of Agriculture.

The task force studied the statistical series published by the ERS on farm retail price spreads for food and the annual food marketing bill. A 40-page publication, "Review and Evaluation of Price-Spread Data for Foods," was published in January 1976 and distributed widely. The task force was chaired by George Brandow, Pennsylvania State University. Other members were D. W. Barrowman, Statistical Reporting Service, USDA; P. A. Baumgart, Safeway Stores; J. W. Hammond, University of Minnesota; G. L. Nelson, Purdue University; R. E. Ward, University of Florida; and G. E. Worden, ERS, USDA.

A member of the Economic Statistics Committee, Norman Coats of Ralston Purina, has been appointed chairman of the Federal Statistics Users Conference's Agricultural Statistics Committee. This committee is planning an active program. Thus, good coordination of the efforts of the two groups is provided.

The committee has received regular reports from Louis Upchurch, the AAEA's representative of the Census Advisory Committee. In addition, there has been informal coordination with the data activities of the Office of Technological Assessment. Without the cooperation of the USDA agencies that collect and publish data, the Statistical Reporting Service, the Agricultural Marketing Service, and the Economic Research Service, the task of the committee would have been more difficult and the results fewer.

At the 1975 meeting of the AAEA, an excellent series of papers was presented on rural, social, and economic statistics under the leadership of Keith Bryant. These papers, in addition to Jim Bonnen's excellent presidential address, have led to significant ferment in the thinking about data by AAEA members.

The major activity planned for the coming AAEA year is a two-and-a-half day workshop in Washington, D.C., in March or April 1977. The proposed title is "Agricultural and Rural Data Workshop: Improvement of Concept in Operation." The workshop will be sponsored and funded by the ERS, SRS, AMS, and the committee. The plans and procedures for the workshop have been reviewed with the Federal Statistics Users Conference and the Office of Technology Assessment. These organizations will be invited to send people to the workshop. Invitations will also be sent to a wide range of data users in industry, universities, and government agencies. The purpose of the workshop is to bring together data producers and users to develop suggestions and recommendations for use by the responsible agencies to improve data and data series. The workshop will focus on conceptual problems, but operational and data flow issues will also be covered.

The workshop will include concurrent half-day sessions on specific topics. At each session a paper will be presented by a team made up of data producers and users. The lead member of each team will be a member of the unit producing the data or series under discussion. Following is a listing of the topics for the half-day sessions and the lead member of each team: (*a*) price reporting—types and levels of transaction (lead member: James Bonnen, Michigan State University); (*b*) price reporting—coverage priorities, value to users, and alternative reports (lead member: James Bonnen, Michigan State University); (*c*) capacity of the food and fiber system (lead member: Earl Swanson, University of Illinois); (*d*) data for indicators of economic well-being of people engaged in farming (lead member: Luther Tweeten, Oklahoma State University); and (*e*) concepts and measures of nonmetropolitan employment, unemployment, and related manpower information (lead member to be selected).

Report of the AAEA Representative on the Advisory Committee for the *Census of Agriculture*

The Advisory Committee met in October 1975 and June 1976. On both occasions the main topic of discussion was the problems and progress of the 1974 *Census of Agriculture*. An early decision by the Bureau of Census to not take a 1974 census and a later mandate from Congress to do so caused delay and confusion in planning and carrying out the enumeration. This contributed to a low rate of response in some areas and to other inaccuracies. Reenumeration was necessary in some areas with unusual efforts for follow-up on nonrespondents. The result was further delay and some sharp resistance by respondents. Some of the more serious problems have been corrected or corrected for, and the computers are running again on a delayed schedule. We will in time get a 1974 *Census of Agriculture*.

Another factor adding to the confusion was the decision by the Bureau (concurred in by the Advisory Committee and U.S. Department of Agriculture) to change the definition of a farm to include only those places with $1,000 or more of sales. The Bureau did enumerate on both the old and the new definitions and will provide "bridge" data to make the 1974 data comparable with earlier censuses.

The ineptness with which the Bureau has handled the 1974 *Census of Agriculture* and the ire of respondents prompted bills being introduced in both the House and Senate that would transfer responsibility for all agricultural data from the Department of Commerce to the USDA (H.R.12397). Hearings were held by the Subcommittee on Census and Population, House Post Office, and Civil Service Committee on 22 and 23 June 1976. I am not aware of any action taken on the bill. An identical bill introduced in the Senate has had no action that I know of. Changing the agency responsible for the *Census of Agriculture* does not necessarily remove some of its more serious problems.

There has been an evident need for a long time to achieve better coordination between the *Census of Agriculture* and other economic censuses. As one step to fulfilling this need, Congress acted to change the dates of the *Census of Agriculture*, authorizing a *Census of Agriculture* in 1978, another in 1982, and subsequent ones in the "2" and "7" years of each decade. This would correspond to the dates of enumeration of other economic censuses. Much more must be done to achieve the coordination needed, but this is one step in the right direction.

M. L. Upchurch

Report of the National Professional Employment Registries Committee

In President Bonnen's letter of appointment of 16 December 1976 he asked the National Professional Employment Registries Committee "to take primary responsibility for (*a*) explaining and promoting the computerized employment registry to other professional groups and potential users and (*b*) to develop a stable financial and organizational basis for continuing the AAEA employment registry when the Labor Department financing ends September 29, 1976." He further wrote that "our overall objective is to establish a solid financial base under our own operation by developing a system of financing and by combining with some configuration of other professional groups" and also said, "I would hope that you would design a feasible run plan for stabilizing our employment registry for the next two years and a long-run road map of the possible and preferred options as we evolve into something of greater scale and/or a different nature."

In an April committee meeting, some aspects of the committee's task were identified and discussed, including the role of the employment registry; advantages of a university base of operation versus a nonuniversity location; budget—survival, short run, and long run; advantages of a national registry including all professionals as opposed to an employment registry including largely those seeking employment; the possibility of producing the *Directory-Handbook* from a national registry data bank; and advantages and disadvantages of combining with other agriculturally related professional associations versus nonagriculturally related groups.

Loys Mather, chairman, Employment Services Committee, was extremely helpful in providing information essential to the committee, including the contact by the U.S. Department of Labor (USDL) requesting an assessment of the possibility of adapting the AAEA system for use by the USDL in recruiting personnel for their Comprehensive Employment and Education Act (CETA) program.

A minimum base budget was estimated assuming no USDL funding and no collaboration with other professional organizations. Circumstances mandated consideration of a survival alternative. This minimum budget was viewed as the base against which to compare other alternatives. The minimum cost of continuing the employment registry is estimated to be about $20,000 per year, assuming location on a university campus with provision of space being the only expected subsidy from the host university. This budget would permit some promotional activity but probably no travel funds for explanation-demonstration by system personnel. In a short-run period of three years, we estimate the cost of a viable, continuing operation to be $20,000–$25,000 per year.

The most feasible possibility for generating $20,000 is user charges, at least in the short run. One possibility that should be explored is the following: (*a*) fifty agricultural economics departments at an average of $250—$12,500; (*b*) U.S. Department of Agriculture (Economic Research Service, Agricultural Marketing Service, Statistical Reporting Service, and Foreign Agriculture Service)—$2,000; (*c*) other organizations (U.S. Agency for International Development, Federal Reserve Banks, and industry)—$4,000; and (*d*) registration fees for each employee registrant on the system (500 employees at $5 each)—$2,500, a grand total of $21,000.

A rough estimate of the reduction in cost to the AAEA by operating the registry in conjunction with another association is, at the maximum, 25%. This means that even in a joint venture under the minimum cost budget configuration it would still cost the AAEA a minimum of $15,000 per year to operate the registry. On the basis of available information we see a very high proportion of variable costs.

There is great long-run potential from possible collaboration with agriculturally related profes-

sional associations. One consideration ties back to a belief that the system can be operated at lower cost on a university campus. We expect the willingness of deans of agriculture to support hosting of the system to be greater if it involves agriculturally related professions.

We recommend exploring the idea of a joint or cooperative registry (probably covering U.S. and Canadian professionals) that would include all individuals in the covered professions. A computerized data base for agriculturally related professions could serve many purposes—to analyze professional profiles, to project manpower needs in a discipline or subdiscipline, to estimate manpower availability, to advise prospective graduate students on manpower needs, and to do objective educational planning. Funds might be obtained to cover at least a portion of the cost of setting up and operating a registry for several professions in order to provide the data for educational planning studies. To the best of our knowledge this has not been done, and at least part of the funding might be forthcoming for a demonstration project.

The committee members agreed on the following. (*a*) The registry should include all professionals, not just those seeking employment, which is necessary if it is to be used for educational planning purposes and as a direct aid for producing *Directory-Handbooks*. (*b*) The AAEA registry should emphasize U.S. and Canadian professionals. Others would be welcome, and the computer should be programmed to maintain separate identity of other groups. (*c*) The name of the registry should be changed, perhaps to Registry for Agricultural Economists.

The following agriculturally related associations were selected for contact by a member of the committee to explore possible interest in collaborating with the AAEA on a computerized professional registry: American Society of Agricultural Engineers, American Forestry Association, American Society of Horticultural Science, Entomological Society of America, American Institute of Biological Sciences, American Society of Animal Science, American Society of Agronomy, and American Phytopathological Society.

Committee members felt it important to explore within the AAEA some of the ideas outlined above regarding the future of the registry. Discussions have already taken place or are planned with the Great Plains department chairmen, Southern Region department chairmen, North Central department chairmen, Northeast department chairmen, Canadian Agricultural Economics Association, U.S. Department of Agriculture, AAEA Industry-Advisory Committee, and the Farm Foundation.

In June the committee reviewed a proposal for a demonstration project to operate and assess a computer-based employment system for agricultural economists and extend operations to CETA prime sponsors. The draft proposal represented an amendment to the then current USDL/AAEA contract, proposing a side-by-side operation of the AAEA and CETA registries in Chicago and incorporating twelve-month funding for the CETA component beginning 1 July 1976 and a nine-month extension of support for the AAEA contract to continue operation through June 1977. The committee recommended to President Bonnen and the AAEA Board that the proposal be submitted to the USDL with minor modifications.

This report is intended to be an overview of progress to date along with "tentative conclusions" pertaining to related issues. We are still in the information gathering and idea testing stage. We plan to formulate recommendations for consideration by the Board and solicit suggestions from any AAEA member.

Report of the Professional Activities Committee

Following the winter meeting of the Board of Directors, President Bonnen reconstituted the Professional Activities Committee, charging it with the responsibility of recommending immediate rule changes, studying the balance between the AAEA's offering of collective and selective goods and examining alternative future configurations for the AAEA. The committee has some overlap with other committees, so it must perform a coordinating function while developing its own plan of work. In the single meeting held to date, several major topics emerged as important themes for future deliberation.

Among the most important is recognition of the large and growing number of subspecialties within the AAEA. Many of these have only tenuous connections with agricultural economics as it has been traditionally formulated. The AAEA faces a fundamental set of choices in developing strong relationships among professionals in the specialties. The information system sponsored by the AAEA may change as the roles of specialties and special interest groups change. A change may yield a set of information disseminating mechanisms quite different from the present *Journal*. Reconstructing the system may yield a number of kinds of publications as well as a central text file with an automated retrieval system that could be used on a fee-for-service basis.

The AAEA is only one of several associations of agricultural economists in the United States today. The relationship between the american association and the regional associations has varied in intensity during the past two decades. In this era of rapid communications and replication of research efforts, all associations will find it advantageous to coordinate professional programs to take advantage of economies of scale and reduce the burden of travel imposed by many associations having separate, uncoordinated meetings. The committee will explore

various possibilities for interassociation cooperation and membership.

The committee recognizes the responsibility of the professional association to aid in maintaining the skills of its members. At present, the AAEA does this only through the annual meeting and the *Journal.* In future meetings, the committee will discuss alternative modes of retraining, updating, and improving skills. These modes will vary in design to suit a wide variety of members working in any of a number of professional capacities.

The AAEA has grown in size and complexity. Both types of growth have required increased time commitments from elected officers and Board members alike. It is rapidly becoming unreasonable for the AAEA to expect universities, government agencies, and private firms to subsidize the official activities of the professional group. The AAEA, its committees, and its Board may wish to consider establishing permanent offices and employing a salaried staff.

In addition to these general themes, the committee makes the following specific recommendations to the Board for its immediate consideration. These recommendations are designed primarily to increase the number of selective goods offered to the AAEA members. (*a*) The AAEA should, in general, limit committee membership to AAEA members. (*b*) Higher registration fees should be charged nonmembers registering to attend the annual meeting. (*c*) The privilege of presenting contributed papers at the annual meeting should, in general, be limited to AAEA members. (*d*) The privilege of presenting and discussing invited papers at the annual meetings should be reserved for AAEA members except in special cases in which the condition is waived by the president. (*e*) Nonmembers should be assessed a page charge of $75 per page on articles accepted for publication in the *Journal.* (*f*) The AAEA president should establish a committee to investigate the possibility of developing a fee structure to be imposed on users of the national registry. (*g*) An appropriate reviewing fee should accompany all refereed papers submitted to the *Journal*'s editorial office.

Report of the Membership Committee

The activities of the Membership Committee during the past year have been divided into efforts directly related to recruiting members for 1976 and efforts related to substantially restructuring the Membership Committee and its approach to membership development in order to enhance future effectiveness.

With regards to direct recruiting activities for the present year, the approach taken was similar to that for the previous two years but somewhat more intensive. Letters were sent to chairmen of economics and agricultural economics departments and heads of agencies asking them to designate recruitment representatives for their institution. When these representatives were designated, they were sent follow-up mailings to assist them in their task and were asked to promote membership in AAEA and in the regional associations. Appropriate materials were provided to them for their task. Special mailings were sent to individual member prospects in the 1890 institutions and in industry. Mailings to these individuals were based on lists of prospective members prepared by David Chen, chairman of the task force for 1890 institutions, and Ed Williams, chairman of the industry task force. Regional task force chairmen for the land grant institutions were involved and provided suggestions, but we were not sufficiently prepared nor appropriately organized at the time for the regional chairmen to be most effective. A final follow-up letter went to all institutional membership representatives in March indicating a "last-chance" opportunity for payment of dues in time to vote and be listed in the new directory.

The activities of the committee were supported by substantial activity on the part of President Bonnen. He met with a number of regional groups to enlist their support and the support of department chairmen in the membership effort.

Bonnen and several members of the committee have been actively involved this year in restructuring the entire approach to membership recruitment and development. Present and prospective members of AAEA are a heterogenous group of applied economists having some common interests and needs but who also identify with subgroups having more specialized and unique interests and needs. There is a growing awareness of the need to approach these subgroups as different target groups for recruitment and for the design of selective goods and services by the AAEA. Accordingly, we now have in place and ready to function a committee whose members are, in effect, chairmen of task forces oriented toward reaching specific membership target groups. The target groups for whom task forces have been organized and chairmen identified are northeastern land grant institutions, southern land grant institutions, midwestern land grant institutions, western land grant institutions, 1890 land grant and related institutions, non-land grant colleges and universities, industries (including cooperatives), foundations and nonprofit institutions, and Canadian institutions. I propose that a task force chairman be added to cover the Economic Research Service and other federal agencies including the Congress.

A meeting of the entire committee is scheduled for 16 August 1976 at Penn State University. The lengthy agenda includes development of specific plans and operational procedure for the committee, specific strategies and plans for reaching the various target groups, the purpose and plan for the institutional membership program, joint payment of

dues to AAEA, CAEA, and the regional associations, improvement of membership statistics, and a number of miscellaneous items. I also hope that we can set some realistic yet challenging membership goals for next year.

I offer the following recommendations. (*a*) The function of the committee should be defined as having emphasis on membership development, that is, on the identification and recruitment of new members. The billing of existing individual members and of institutional members should be handled by the secretary-treasurer. Presently, there is some confusion about who has responsibility for billing institutional members. (*b*) We should work toward computerization of membership lists and accounting systems for the AAEA. (*c*) If the membership list can be computerized, we should publish the *Directory-Handbook* more frequently, possibly every two years with the printing cost borne by advertisers or by institutional members. The directory-type data for individuals that would be available on a computerized membership list would be valuable information for use by the committee in identifying present membership and target groups for further membership efforts. The same data would also be valuable for developing selected mailing lists for delivery of selective goods and services by the AAEA. Such a list and the associated information on individuals would also be useful to the president and the Board for the purpose of making committee appointments, etc.

The committee will likely have further recommendations to make to the Board following the 16 August meeting. These recommendations will be submitted to the Board prior to its fall meeting.

Again, the Committee would like to express its appreciation for the personal interest and support of President Bonnen and for the untiring efforts of our secretary-treasurer, John Redman.

John E. Lee, Jr., *chairman*

Report of the Extension Affairs Committee

The Extension Affairs Committee was appointed in December 1975. Since that date the chairman and members of the committee have conducted an active correspondence. Our first assignment from President Bonnen was to advise him regarding the desirability of a session on extension affairs at the annual meetings in August 1976. A caucus of the committee was conducted and recommendations forwarded to President Bonnen.

The major charge given to the committee was to identify, design, and implement new "selective goods" that would be of value to extension members. An active correspondence among committee members has sought to identify such goods.

Among the possible courses of action being debated currently is a survey of extension economists concerning their views of the AAEA as it relates to the needs of extension professionals. This survey would attempt to specifically identify the services currently offered by the AAEA through the organization, the *Journal*, and the annual meetings that are of value to extension members. Second, we would solicit positive suggestions for improvement in services offered to the extension economist.

Other ideas that have been suggested by members of the committee include a special issue or supplement to the *Journal* devoted to extension affairs, professional meeting sessions concurrent with the annual meetings or entirely separate, and a workshop or workshops on issues facing extension sponsored by the AAEA.

It is hoped that several members of the committee will be able to meet at the annual meetings in August to discuss courses of action for the coming year.

Robert L. Christensen, *chairman*

Report of the Industry Advisory Committee

The AAEA has the tremendous value of establishing an environment in which all groups of agricultural economists can provide their inputs to the profession. During the past year the Industry Advisory Committee has worked at providing this input via the annual meetings. We are sponsoring an industry banquet and an invited papers session at the 1976 annual meetings.

The committee would like to offer more ideas with the following recommendations to the Board of Directors. (*a*) An "open letter" should be sent to all AAEA members to express concern with the current employability of agricultural economists. (*b*) The committee should continue to sponsor a banquet and invited papers session at the annual meetings. (*c*) Industry agricultural economists should be encouraged to respond formally to articles in the *Journal*. Industry agricultural economists would be much more able to give short responses to published articles as opposed to being asked to write lengthy formal research articles for the *Journal*. (*d*) The industry representative on the Board of Directors should be a member of the Industry Advisory Committee. (*e*) A section of the agenda of each AAEA business meeting should be devoted to receiving input from the various "groups" within the AAEA. (*f*) The AAEA should work towards providing a forum through which the profession can respond to current topics in policy or market. (*g*) The Board should consider having fewer contributed papers sections at the annual meetings with a simultaneous attempt to improve the professionalism of these sessions. (*h*) The AAEA should develop and mail to all members a quarterly calendar of relevant workshops and seminars being offered by universities, associations, consulting groups, etc. (*i*) Sustaining membership dues should be kept at $100.00 per year, but all

sustaining members should be invited to take out an advertisement in the *Handbook-Directory*. The cost of such an advertisement could be $100.00 per year. Therefore, sustaining members taking an advertisement in the *Directory* would pay $200.00 per year to the AAEA.

Paul A. Baumgart
Charles E. Erickson
Eugene Gerke
W. Bernard Lester
Walter M. Myers
Ted Rice
Bruce A. Scherr
Ed Williams
Arthur G. Wilson

Report of the International Committee

Work of the committee in 1975–76 was concentrated on the five recommendations from the 1973–74 *Review of International Training* on which the Executive Board had asked the committee to follow up. Some attention also has been given to an additional problem.

Action on 1973–74 Recommendations

Recommendation #1 is that a meeting of appropriate officials be convened to examine issues of training needs. Since an interagency committee was being formed by the USDA, AID, and NASULGC to consider arrangements for international training, we considered how we could relate ourselves to this committee. We therefore initiated an exchange of correspondence between President Bonnen and Don Paarlberg (cochairman with Elmer Kiekl of the International Science and Education Committee). We asked Peter Timmer to extend his liaison role if a follow-up opportunity presented itself. Don Paarlberg was provided with a copy of the committee's "1973/74 Report on International Training in Agricultural Economic Development." Our committee has had no further communication from the USDA/AID/NASULGC committee. The International Committee should give further consideration to recommendation #1 in the coming year.

Recommendation #2 is to evaluate benefits that have been derived from international travel grants. We did not see any way we could constructively assess this question at reasonable cost, so no action was taken.

Recommendation #3 is with respect to sessions at the 1976 annual meetings. Our committee organized an invited papers session on "Small Farmers Resources in Rural Development: Current Research and Application" and an international dinner.

Recommendation #4 relates to improvement of placement and admissions policies and practices. Our committee has communicated with the American Association of Collegiate Registrars and Admissions Offices, the National Association for Foreign Student Affairs, and the Economics Institute (University of Colorado) and has studied materials from these bodies pertaining to evaluations of foreign students and foreign institutions. We considered the desirability of asking the AAEA to name a liaison person with one or more of these agencies but do not think it advisable at this juncture. At a 17 August meeting, the committee will consider framing a note on the services available from these groups for insertion in the *Journal*.

Recommendation #5 related to a sample survey of foreign agricultural economists regarding their U.S. graduate training. James Houck has outlined a possible study for consideration at the 17 August meeting of the committee. Our recommendations will be submitted subsequently to the AAEA president or to the next International Committee chairman, as is appropriate.

Other Activities of the International Committee

Committee member Peter Timmer, the AAEA liaison with RTN/ADC, has summarized his activities in a letter of 17 June to President Bonnen.

The committee is concerned with the deteriorating support for international agricultural economics research at U.S. universities and research centers. This diminished support, and thereby diminished interest, has meant a cutback in the number of personnel engaged in international research, teaching, and training, and such a cutback most drastically affects the hiring and retention of young professionals just beginning their teaching and research careers.

The impact has been that many young, able, well-trained economists with strong interests and significant field experience in the problems of less developed countries are no longer able to find research and/or teaching positions in those universities that historically have maintained large enough international programs to attract a critical mass of experienced scholars committed to understanding and solving those problems. Consequently, many of these young economists are now teaching at universities, colleges, and junior colleges that have no active programs in international economics and no other professionals interested in the problems. In short, these young economists find themselves isolated outside the (now diminished) mainstream of research interaction that is characteristic of the larger and identifiable programs.

The problem is how to avoid losing these young and committed professionals to the field of international agriculture. The committee feels that some effort should be made to determine the overall seriousness of the problem and to recommend desirable steps to alleviate it. The problem will be further considered at the 17 August meeting.

Report of the Resident Instruction Committee

Much of the emphasis of the committee this past year pertained to developing a program for the resident instruction session and to assisting the undergraduate officers with their program for the annual meeting. The format of the resident instruction session for the summer meeting includes two invited papers, with discussants, and time for group interaction. The committee believes that these formal comments, focusing on instructional needs in a changing world, should provide a good "springboard" for continued group discussion.

The undergraduates are allowed to submit papers to either the "regular" contributed papers section or to a "special" undergraduate contributed papers section. The papers submitted to the regular section are being treated in the same manner as for professionals. However, the papers submitted to the "special" section are being screened and numerically evaluated by selected numbers of the committee. The oral presentations for the "special" group will also be evaluated at the annual meeting. This then allows for special recognition (a certificate prepared by the committee) to be given to undergraduates preparing and presenting outstanding papers.

Our committee believes that the student contributed paper session has a definite professional posture and one that will be attractive to undergraduates. Of course, the extent of interest and the degree of success is unknown but will be evaluated.

The committee has no recommendations for changes. It wants to first gain experience with this format.

Lonnie L. Jones
Walter J. Wills
James G. Kendrick
Hong Lee
Larry E. Johnson
Milton M. Snodgrass
A. Robert Koch
Glenn C. Himes, *chairman*

Report of the Committee to Review the AAEA Constitution and Bylaws

The committee was appointed in October 1975 to review the governing documents of the AAEA. The committee made no recommendations for change in the articles of incorporation and constitution. Several recommendations were made in the final committee report to the executive Board at the August 1976 meetings for amendment to the bylaws. Amendments to that document require a majority vote of the Executive Board.

In addition to its own review of the AAEA documents and organizational structure, the committee also obtained suggestions from the Executive Board at the December 1975 meetings in Dallas, the editor of the *Journal,* the committee to review the fellows selection process, and the present and past chairmen of the awards committee.

The committee's final recommendations for amendment to the bylaws are of several types: (*a*) actions of the Executive Board, since its creation in 1968, that should by virtue of their policy nature be included in the bylaws; (*b*) policies and procedures of some standing committees that involve the membership to a substantial degree, and (*c*) suggestions from the committee and other interested individuals.

The specific recommendations include several editorial changes as well as the following substantive suggestions for amendment: elimination of the classification of "corresponding" members; redesignation of "sustaining" membership category to "institutional"; permission for a duly designated representative of a department to countersign applications for junior membership; reflection of the scale of dues approved by the membership in August 1975; nomination procedure for fellows modified including the addition of a requirement that a nominee be "a current member of the Association in good standing or have been a member thereof for at least ten years"; the maximum number of newly selected fellows increased from three to four annually; the fellows election committee procedures modified to include an annually revolving chairmanship selected from among members of the committee and a sixth committee member as the designated representative of the Executive Board; revision of procedures for the awards program based upon criteria and procedures in use; a provision that the AAEA president, in consultation with the Executive Board, is responsible for preparing the program for the annual meeting; revision of procedures for selection and evaluation of positions filled by appointment in the AAEA; codification of changes approved earlier on election procedures; increase in authority of the secretary-treasurer to borrow funds on behalf of the AAEA without further Executive Board authorization from $10,000 to $25,000; change in the list of standing committees to reflect current committee status as approved by the membership; change made to show the name "Resident Instruction Committee" rather than "Student Affairs Committee"; creation of a new article in the *Journal* with sections on the role of Executive Board, the role of the editor, and the role of the editorial council.

The committee also makes the following recommendations to the Executive Board. (*a*) The importance of precision in amending the bylaws be emphasized. In particular, problems may be created when the responsibility for amendment drafting is left to the secretary on an *ex post* basis. The committee suggested that, as a matter of practice, the minutes reflect the precise wording of any amendment of a governing document initiated or given final approval, as the case may be. (*b*) The governing documents, and particularly the bylaws, be

kept up to date with amendments added as enacted and that newly elected members to the Executive Board be given up-to-date copies of all three governing documents. (*c*) Whenever actions are taken relative to policy matters, the Executive Board consider whether such actions should be memorialized by inclusion in the governing documents. (*d*) Minutes of the AAEA, both with respect to meetings of the membership and of the Executive Board, be relatively complete and reflect fully the AAEA's actions and activities.

John E. Kadlec
John C. Redman
Neil E. Harl, *chairman*

Report of the Visiting Lecturer Committee

For a number of years the AAEA sponsored a Visiting Lecturer Program. The program has been successfully used by some schools, but it has not been as widely used as had been expected. This year, President Bonnen asked the Visiting Lecturer Committee to expand its function by considering other activities that might be feasible for the AAEA to undertake in order to improve services and communications to members outside the land grant system.

In accordance with this charge, the committee devised a questionnaire designed to elicit ideas about the kinds of assistance the AAEA might help provide faculty and students located in these institutions. Conclusions from this survey are as follows. (*a*) Respondents indicated a strong preference for assistance with instructional compared to either research or extension programs. (*b*) In providing assistance with instructional programs there was a stronger preference for workshops than for visiting lecturers or consultants. (*c*) Several ways were suggested for increasing communication between members of these institutions and other professionals. The alternative receiving the strongest preference was for special sessions at the annual meeting of the AAEA for discussing programs of these institutions.

Given the preferences of the responders to our questionnaire and assuming the AAEA desires to improve services and communications with members in these institutions, the committee requests permission from the Board to work with representatives of those institutions in planning a session, for next year's summer meetings, designed to meet their specific needs.

W. Neill Schaller
Willard W. Cochrane
T. T. Williams
R. Vern Elefson
John Sjo
Wayne Purcell
William Herr, *chairman*

Minutes

Minutes of the Executive Board Meeting, Dallas

The meeting was called to order by President Bonnen at 8:00 a.m., 27 December 1975.

Present: Voting members:
Bonnen, Farrell, Nielson, Mangum, Stanton, Barr, Heitz, Raup, Robinson
Members ex officio:
Redman, Tomek
Guests:
Ackerman, Rasmussen, Holt, Lee, Harl

1. Bonnen reviewed the agenda for the meeting.
2. Stanton moved the approval of minutes of the summer meeting of the Executive Board at Columbus. Seconded. Passed.
3. Redman gave a preliminary report on the membership, financial condition, and investments of the AAEA, pointing out that all *ABAE* refund checks ($4,149) had been mailed, cash flow problem had been solved, *Handbook-Directory* forms were mailed, prepaid dues for 1976 were lagging, etc.
4. Tomek reported as editor of the *Journal,* discussing problems associated with size, scheduling, pricing of reprints, advertising, pricing of old issues, etc. It was the consensus of the Board that the editor and the secretary-treasurer develop the best alternative bid for *Journal* printing for consideration at the next Board meeting.
5. Stanton reported for the Finance Committee indicating that the committee will meet as soon as possible after the end-of-year data become available.
6. Barr moved that all single copy issues of the *Journal* be set at $10.00 each, effective with February 1976 issue. This applies also to all issues in inventory. Seconded. Passed.
7. Farrell reported for the Bibliographic-Retrospective Search Committee. After discussing the suggested ways to publicize the retrospective search system, Stanton moved that the committee's suggestion to defer the publication of author-title lists in the *Journal* be accepted and that all five alternative suggestions be implemented as soon as possible, namely, (*a*) develop a brochure describing the system and include a copy in bulk mailing to members; (*b*) send a letter to all department heads, discussing the system, the hardware, and financial aspects of its use; (*c*) arrange the annual report of the American Agricultural Economics Documentation Center to give data on use of the system, with entries by author and institution, and other operating information; (*d*) insert a one-page announcement in each issue of the *Journal;* and (*e*) give a live demonstration of the system at the meeting at Pennsylvania State University. Seconded. Passed.
8. Ackerman reported on the National Employment Registry for Agricultural Economists, indicating that the supplemental grant from the U.S. Department of Labor would expire 29 September 1976. President Bonnen announced the appointment of the Committee on National Professional Employment Registries to explain and promote the computerized employment registry to other professional groups and potential users and to develop a stable financial and organizational basis for continuation of the registry.
9. Rasmussen reported on possible approaches to a historical study of the agricultural economics profession and the AAEA. Bonnen and Farrell will further evaluate activities that might be appropriate for the AAEA.
10. Robinson reported that work on the *Handbook-Directory* was proceeding on schedule. The *Handbook-Directory* Committee will recommend a price for the issue at the August meeting of the Board.
11. Barr presented a summary of the final report on the 1975 meeting at Columbus, indicating that the budget was balanced but included a substantial subsidy by Ohio State University in the amount of at least $3,500. A copy of the detailed report was sent to the secretary-treasurer and to Pennsylvania State University. Nielson moved acceptance of the report with a special thanks to Ohio State University for hosting the meeting. Seconded. Passed.
12. Holt reported on preparations for the 1976 meeting at Pennsylvania State University. He indicated that meals can be had as a package or individually at the cafeteria. The administrative fee of $4,000 covers handling of registration, mailings, conference services, etc. Air commuter service would be provided from Pittsburgh to State College, etc. Stanton wanted to be recorded that he believed the differential in registration fee for single versus families is too small. After discussion, Stanton moved that the registration fee be $15 for single and $20 for a family. Seconded. Passed.
13. Barr moved that the 1976 meeting be held jointly with the Northeastern Agricultural Economics Council. Seconded. Passed.
14. Farrell discussed the program being planned for the Atlantic City meeting in September 1976, pointing out the need for greater coordination with the August 1976 meeting.
15. The Board discussed the need to shift the time of the Board meeting usually held in December at the same time as the Allied Social Science Associations meetings. Consensus was that, when the ASSA meets in early fall, the AAEA

Board meeting should be in the winter, preferably during the first week of January.

16. Farrell reported briefly on the plans for the 1977 meeting in San Diego.

17. Bonnen sought the Board's reaction to appointment of two ad hoc committees, an Alternative Publications Committee to look at objectives, format, and cost of publications other than the *Journal* and a committee to evaluate annual meeting programs. The consensus was one of support. Bonnen announced the discharge of several ad hoc committees, including the Committee to Review AAEA Affiliation with CAST and also the Bibliographic-Retrospective Search Review Committee. He announced also the appointment of a Committee to Review the Constitution and Bylaws and a Committee to Review the Fellows Selection Process, in addition to the Committee on National Professional Employment Registries.

18. Stanton moved the discharge of the "Publications Policy Review Committee." Seconded. Passed.

19. Bonnen discussed a strategy to strengthen the AAEA through improved services to members, recruitment of new members, and revival of the Professional Activities Committee. The Committee will deal with the impact on the AAEA of the growing diversity of specialization in the profession by designing new AAEA services and rules governing AAEA services.

20. Lee reported on plans for the membership committee.

21. Harl reported on the findings of the Bylaw Review Committee and sought Board guidance on specific categories of bylaw changes, namely, those changes having been adopted in general form previously, those appearing to be needed and noncontroversial in nature, and those having been suggested but needing further study. They were considered in reverse order and the following actions were taken. (*a*) Article II, Section 2, deleting classification of corresponding members, was approved. (*j*) Article VI, Section 1, stipulating that the cerning the rules governing the selection of fellows, was referred to an ad hoc committee for study and report by the August meeting. (*c*) Article VI, Section 2, requiring the announcement of committee appointments at the annual meeting or as soon thereafter as possible, was not approved. (*d*) Article VIII, Section 6, raising the limit the secretary-treasurer may borrow without further authorization to $25,000, was approved. (*e*) Article XII, Section 4, stating policy that AAEA does not assume responsibility for travel or other expenses associated with committee activities; was approved. (*f*) Article II, Section 2(b), permitting a designated representative of a department to attest to student membership status, was approved. (*g*) Article II, Section 2, allowing the institutional member one vote but to have up to three representatives, was approved. (*h*) Article XII, Section 1, listing the standing committees as awards, audit, editorial council, fellows election, finance, membership and institutional membership, professional activities, resident instruction, and tellers, was approved. (*i*) Article VII, permitting the secretary-treasurer with the approval of the Board to deviate from the U.S. balloting procedures for the foreign membership, was approved. (*j*) Article VI, Section 1, stipulating that the president in consultation with the Executive Board shall be responsible for preparing a program for the annual meetings, was approved. (*k*) Article VII, Section 1, implementing the current election procedures, was approved. (*l*) Article V, expanding the description of each award but not the criteria and the recommendation that the present and recent past chairmen of the Awards Committee be consulted on appropriate wording and format, was approved. Finally, (*m*) Article XIII, on student activities, was recognized to be developed.

Further, Harl, speaking for the committee, recommended that future bylaw changes be presented to the secretary in writing with precise wording so the minutes will reflect the exact approved change. Other recommendations included procedures to keep the bylaws up to date and available to Board members, maintaining important policy statements, and the degree of brevity of minutes. Farrell moved that these be accepted in principle and that the secretary-treasurer and the president reflect on how they be implemented and report by the August 1976 meeting. Seconded. Passed.

22. Babb reported on the alternative proposal for volume I of the *Postwar Literature Review*. The three proposals presented were (*a*) AAEA to act as its own publisher; (*b*) AAEA to enter into a joint venture with a major publisher; and (*c*) AAEA to make a grant-in-aid to a publisher. Nielson moved that the third proposal be adopted. Seconded. Passed.

Nielson moved that AAEA enter into a contract with the University of Minnesota Press under the option that involved a grant of $7,500 from AAEA. The option called for the book to sell at $25 per copy with a discount to members whose dues are paid by the time of the order, no discount to subscribers, and a 20% royalty to be received on nondiscounted sales. Seconded. Passed.

23. Nielson moved that AAEA impose a page charge on invited papers (not invited addresses such as fellow's address, presidential address, etc.) with the president having the perogative of granting specific exemptions when necessary.

24. Bonnen reviewed the program being planned for the August 1976 meeting.

25. After studying and discussing the supportive documentation on each person nominated for fellow, seven names were selected, and Barr moved that they be submitted to the Fellows Selection Committee. Seconded. Passed.

Adjourned at 5:30 p.m., 29 December 1975.

Respectfully submitted,
John C. Redman
Secretary-Treasurer

Minutes of the Executive Board Meeting, State College

The meeting was called to order by President James T. Bonnen at 8:40 a.m., 14 August 1976.

Present: Voting members:
Bonnen, Raup. Mangum, Nielson, Heitz, Farrell, Barr, Robinson, Stanton
Members ex officio:
Redman, Tomek, Martin, Sargent, King
Guests:
Hildreth, Holt, Malone

1. Holt and Malone reported on the local arrangements, indicating 1,037 had preregistered.

2. Bonnen reviewed the agenda, pointing out that most reports would be presented and received for later action at this meeting.

3. Mangum moved the approval of the minutes of the winter meeting of the Executive Board held in Dallas and as distributed. Seconded. Passed.

4. Bonnen presented the reports of the Tellers and Fellows Election Committees. R. J. Hildreth is the new president-elect and Sylvia Lane and Richard Crowder are the incoming directors. E. N. Castle, A. T. Mosher, and W. F. Mueller are the new fellows.

5. Redman distributed the secretary-treasurer's report and the AAEA investments report, which will be presented at the general business session.

6. Stanton, chairman of the Finance Committee, reviewed the financial needs of the AAEA in relation to income. The committee asked the Board to establish an investment policy. Heitz moved that the AAEA investment policy shall be to maintain the purchasing power of the fund and, within that constraint, the goal should be to maximize annual earnings. Seconded. Passed.

7. Redman distributed the audit report of the certified public accountant, and Bonnen read the report of the Auditing Committee, which will be presented at the general business meeting.

8. Tomek distributed and commented on the editor's report, which will be presented at the general business session. As instructed previously, Tomek and Redman presented a set of alternative prices for *Journal* reprints. After a discussion of increasing costs and the related issue of "free" reprints to those honoring the page charge, Nielson moved that a reprint price schedule be adopted that will reflect approximately a 50% increase on the first 100 copies, a 40% increase on additional 100 copies, and a 20% increase on regular *Journal* covers. Seconded. Passed.

Stanton moved that advertising rates be increased 40%, making the price of a full-page ad \$210, a one-half page ad, \$115, and a quarter-page ad, \$70 in one issue. Seconded. Passed.

Tomek further reviewed the policy on page charges, indicating a troublesome problem exists in determining the validity of requests for financial exemptions from the charge. The editor's experience to date has raised certain issues. The policy is that the page charge is mandatory and only the president and the editor have the power to grant specific exemptions on a case-by-case basis. Nielson suggested that an ad hoc committee be appointed to study the page charge procedures and provide a revised statement stating the policy more clearly. The consensus was that Farrell, the incoming president, will appoint the committee.

9. Mather reported for Employment Services Committee on the possibility of using the information in the registry for the *Handbook-Directory*. The basic decision at this point is whether further study and planning should be done into producing future *Handbook-Directory*'s from the registry. Mather reported also that 2,094 professionals are now registered.

Farrell will ask the Employment Committee to explore the feasibility of using the registry data for the *Handbook-Directory*.

Mather reported on the proposal to the U.S. Department of Labor to modify the demonstration project to incorporate the professionals employed by the Comprehensive Employment and Training Act (CETA) organizations and prime sponsors into a system to be developed and operated side by side with the AAEA registry for one year. After much discussion, Stanton moved to authorize the president to make the AAEA a party to the Illinois-CETA proposal and if arrangements with CETA fail then to explore with other associations. Seconded. Passed.

10. Boyne reported on the progress of National Employment Registries Committee, charged with exploring with other professional groups the use of the computerized employment registry and developing a stable financial and organizational basis for continuation of the AAEA registry. He estimated the minimum cost of a self-sustaining registry to be \$20,000. Boyne reported on possible approaches to generating the minimum \$20,000 support. He also indicated that other agricultural associations are being contacted about the possibility of a joint endeavor.

11. Barkley reported for the Professional Activities Committee with some recommendations governing current AAEA services designed primarily to increase the number of selective goods and services offered to the AAEA membership.

Farrell moved that in general that AAEA committee assignments be limited to active members. Seconded. Passed.

Mangum moved that higher registration fees be charged nonmembers registering to attend annual meetings. Seconded. Passed.

Nielson moved that the privilege of presenting and/or discussing contributed papers, invited papers, and invited addresses at the annual meetings be reserved for AAEA members, except in special cases in which the condition is waived by the president. Seconded. Passed.

Farrell moved that the recommendations (*a*) that nonmembers be assessed a page charge of $75 on articles accepted for publication in the *Journal* and (*b*) that a submission fee to accompany all refereed papers submitted to the *Journal* be referred to a Page Charge Committee to be appointed. Seconded. Passed.

The recommendation that AAEA awards be made to members only was referred by consensus to the Awards Committee.

The recommendation that at least one author of articles accepted for the *Journal* be an AAEA member was deferred by consensus for further study.

12. Barr, reporting on the study of alternative bids for renewal of the *Journal* printing contract, moved that a three-year printing contract for the *Journal* be negotiated with the lowest bidder, Edwards Bros., Ann Arbor, Michigan, with the following conditions: (*a*) the 9% discount offered for one year off the printing and binding costs quoted be finalized, (*b*) the maximum annual price escalation be limited to the annual increase of the U.S. Consumer Price Index, (*c*) additional savings be negotiated on the quality of the cover with the true green color being retained, type of binding, paper, etc., and (*d*) that acceptance of the Edwards Bros. bid shall be contingent upon successful negotiation of important miscellaneous items, such as reprint pricing, mailing costs, further verification of satisfactory performance, etc., which were inadequately specified in the bid. Seconded. Passed.

13. Gerke reported for the Industry Advisory Committee recommending (*a*) that the committee's "open letter" concerning the employability of agricultural economists be sent to all AAEA members and (*b*) that the committee continue to sponsor a banquet and invited papers session at the annual meetings. By consensus, the "open letter" will be included or coordinated with the mailing of one of the president's letters.

14. Lee reported for the membership committee recommending (*a*) that its emphasis be on identification and recruitment of new members, (*b*) that the billing of existing individual and institutional members be handled by the secretary-treasurer, (*c*) that work toward computerizing of the membership list be considered, (*d*) that the AAEA president and each regional association make joint appointments to the membership committee, (*e*) that the AAEA consider joint mailing of dues notices but that the associations not collect each other's dues, and (*f*) that an ad hoc task force be appointed to review current billing procedures.

The consensus of the Board was that there be an exchange of membership lists between regional associations and the AAEA and that action be taken on joint mailing of dues notices by the AAEA.

15. Robinson reported for the *Handbook-Directory* Committee and indicated that it was on schedule. After presenting two alternatives for the price of the *Handbook-Directory* to nonmembers, Robinson moved that the price be $15 each and that we print 9,000 copies. Seconded. Passed.

16. Farrell reported for the Bibliographic-Retrospective Search Committee.

17. Farrell reported on the travel grants to the IAEA meeting in Kenya, indicating that forty-one applied for the ten grants sponsored by AAEA. Recipients of the AAEA grants, totaling $4,900, were Malcolm Bale, Montana State University; Derek Byerlee, Michigan State University; Leroy Davis, Southern University; Brady Deaton, University of Tennessee; Charles Hanrahan, FDCD-ERS-USDA; Margo B. Rich, Food Research Institute; Kenneth Shapiro, University of Michigan; Robert Thompson, Purdue University; E. M. Wilson, Virginia Polytechnic Institute and State University; and Donald Larson, Ohio State University.

18. Hildreth reported for the Economic Statistics Committee and reported on plans for the Agricultural and Rural Data Workshop to be held in Washington, D.C., in March or April 1977 in cooperation with SRS-ERS and AMS of the USDA.

19. Harl, reporting for the Bylaws Revision Committee, presented the final version, incorporating the provisions previously approved by the Board and the provisions delegated to committees (e.g., fellows selection, awards, etc). Stanton moved that Article II, Section 2, be changed to allow any member in good standing to certify the eligibility for junior membership. Seconded. Passed.

Barr moved that the bylaws as prepared and distributed, with the change just made, be adopted. Seconded. Passed.

20. Bonnen and Redman presented suggestions for implementing four procedural recommendations made by the Bylaw Review Committee. (*a*) Upon request of the secretary-treasurer, all Board members who have introduced motions subsequently approved by the Board in any session should provide their motion in written form to the secretary before the meetings of the Board are adjourned. The Board is responsible for reviewing the written drafts of its approved motions for confirmation of original intent before it adjourns. (*b*) Members of the Executive Board should have their own copies of AAEA governing regulations at each meeting. The secretary shall provide all Board members with an updated version of the Constitution and bylaws in an appropriate form at the winter meeting of the Board. (*c*) All policy actions of the Board that are of more than a temporary nature shall be included in the bylaws. The president shall designate a member of the Board to prepare a draft of proposed bylaw changes or additions, memorializing the relevant policy actions arising out of the Board meetings held during the president's term of office. The proposed bylaw changes and additions shall be submitted for final approval of the Board before adjournment at its summer meeting or immediately thereafter. (*d*) The minutes of the Board shall in-

clude for the permanent record the following major items. Motions are to be made with a brief summary statement of intent underlying the motion if not obvious. Committee reports requesting specific action by the Board shall be in final form suitable for publication with copies to the editor and secretary so motions can be referenced to the report. Reports with no request for action or progress reports are to be noted only. Major problems or issues raised will be noted with no reference to views held by individual Board members.

Nielson moved the approval of the procedures. Seconded. Passed.

21. Farrell reviewed the many concerns that have been advanced regarding the contributed papers rules. Weeks, Coffey, and Boyne as chairman and former chairmen of contributed papers program offered comments. The general consensus was that this popular activity should be reevaluated because of some inherent problems, such as quality control.

22. Bonnen reported that the contract for the second volume of the *Postwar Literature Review* was ready for signing. It contained essentially the same provisions as the contract for volume I.

Stanton moved that the ad hoc committee on Publication of *Postwar Literature Review* be authorized to proceed with the contractual agreement with the University of Minnesota Press, subject to the stipulation that the University of Minnesota Press has only the "right of first refusal" for publication of volume III. Seconded. Passed.

23. An increasing number of requests to the AAEA president to endorse various symposia, conferences, etc., are occurring. Considerable discussion ensued concerning the limits and the role of AAEA in providing selective and specialized services, etc. The president assigned this to the Professional Activities Committee for development of policy statement and guidelines for Board consideration.

24. Richard King, as president of Southern Agricultural Economics Association, Fred Sargent, as president of Northeastern Agricultural Economics Council, and William Martin, as president of Western Agricultural Economics Association, each commented on relationships with the AAEA, emphasizing the need for closer cooperation with the regional groups. The Northeastern and Western Associations are now undertaking the publication of a journal.

25. Tomek asked for clarification of policy regarding the materials published in the proposed WAEA journal being eligible for consideration in the *Journal*. Previously, the material appearing in the WAEA's one issue, a proceedings issue, was considered eligible. Nielson moved that publication in the new WAEA journal be considered prior published material and hence not eligible for publication in *Journal*. Seconded. Passed.

26. Stanton reported for the Finance Committee and presented a budget of $191,200 for 1977, which is essentially a breakeven budget between income and expenses. After a discussion of high, medium, and low membership projections, Stanton moved that the medium level of 5,575 members and subscribers (3,300 regular members) be used for budgetary purposes and that the budget be approved. Seconded. Passed.

27. Farrell reported on the meetings scheduled with the Allied Social Science Associations in Atlantic City, 15–18 September 1976.

28. Redman presented three possible commercial sites for 1979, since no firm invitations had been received from universities. The consensus was that every university possibility should be explored first, particularly with those that have expressed some interest in the past.

29. Bonnen expressed his appreciation to the members of the Board for their assistance and especially to the retiring Board members, Glen Heitz and Howard Robinson, and to the past president, James Nielson, for their period of service.

30. Board recessed at 6:00 p.m.

Respectfully submitted,
John C. Redman
Secretary-Treasurer

Reconvened on 18 August at 11:40 a.m. with President Kenneth Farrell presiding.

Present: Voting members:
Farrell, Bonnen, Hildreth, Barr, Crowder, Lane, Mangum, Raup, Stanton.
Ex officio:
Tomek, Martin, King.

1. Farrell discussed the plans for the 1977 annual meeting to be held in San Diego on 31 July–3 August, outlining the nature and cost of facilities at the Town and Country Hotel. There will be no cost for the meeting rooms, and hotel rooms will range from $23 to $26 for single rooms, $28 to $31 for double rooms, and $4 for the third and/or fourth person occupying the same room and existing bedding. Certain other services such as registration assistance, name tags, etc., will be provided with no charge. The nature of the program, balance among invited papers, regular contributed papers, and self-invited sessions were principal topics of Board discussion.

2. Locations of future meetings were discussed. Lane moved that Washington State University for 1979 and the University of Illinois for 1980 be invited to host the AAEA meetings. Seconded. Passed. President Farrell will proceed with the invitations.

3. Hildreth moved that the president be authorized to issue an invitation to the Canadian Agricultural Economics Society to participate in a joint meeting with AAEA in 1978 at Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Seconded. Passed.

4. Farrell discussed committee assignments for directors for 1976–77. Among the appointments

were Mangum on the Alternative Publications Committee, Crowder on the Industry Advisory Committee, and Lane on the Membership Committee.

5. President Farrell will be inviting nominations for editor. He appointed Hildreth, Lane, and Tomek with Farrell as chairman to serve as an ad hoc committee to review the nominees and to make a recommendation to the directors at the winter meeting.

6. The tenure of an AAEA liaison representative to various groups was discussed. Bonnen moved that such representatives be limited, in general, to two three-year terms. Seconded. Passed.

7. Farrell discussed some proposals that are an outgrowth of his presidential address. The directors concurred in (*a*) referring the public policy award idea to the awards committee for consideration, (*b*) referring the idea of AAEA sponsored symposium, seminars, etc., to the Professional Activities Committee and asking that committee for an interim report in January, (*c*) forming an ad hoc committee on the possibility of inviting public policy papers but without commitment to a specific form of publication, and (*d*) forming an ad hoc committee to explore the feasibility of a public policy institute.

8. The winter meeting of the Board will be held on 3–4 January 1977 in Washington, D.C.

9. After considering a request for AAEA to cosponsor a symposium on trade and trade policy, the Board decided not to sponsor any symposium until the Professional Activities Committee has made its report on establishing a policy and guidelines for such activities.

10. Barr reported some further details on the *Journal* printing contract.

11. Farrell discussed appointments to committee chairmanships.

12. Bonnen commented on the need for continued AAEA communication with regional associations and with departmental chairmen.

13. Board adjourned at 1:50 p.m.

Respectfully submitted,
William G. Tomek
Acting Secretary

Minutes of the Annual Business Meeting, State College

The 65th annual meeting was called to order by President James T. Bonnen at 8:45 a.m.

1. President Bonnen presented for approval the minutes of the annual business meeting held at Columbus, Ohio, 12 August 1975, as published in the proceedings issue of the *Journal*. Motion was duly made. Seconded. Passed.

2. Bonnen announced officially the results of the election. R. J. Hildreth was elected president-elect, and Sylvia Lane and Richard Crowder were elected directors.

3. Redman presented the secretary-treasurer's report for the fiscal year, 1 January 1975 through 31 December 1975. Redman also presented a report on AAEA investments for 1975.

4. Bonnen presented the Audit Committee Report for 1975, which incorporated the opinion of the certified public accountant employed by the AAEA.

5. Tomek reported as editor of *Journal*.

6. President Bonnen highlighted the activities of the Executive Board. (*a*) The AAEA reprint and advertising rates have been adjusted. (*b*) A policy was established to safeguard the purchasing power of AAEA investments and within that framework to maximize the income stream. (*c*) The *Handbook-Directory* will be published November 1976. (*d*) The Bibliographic-Retrospective Search is now on line. The National Agricultural Library and Pennsylvania State University are cooperating in providing a demonstration at the meetings. (*e*) The Resident Instruction Committee has developed a new format for student programs. (*f*) The Economic Statistics Committee continues to work on the data base for agricultural economics. (*g*) The bylaws have been revised with no change in the constitution. (*h*) A committee has begun a systematic evaluation of changes, if needed, in the annual meeting program. (*i*) In appointing committees this year, the president reviewed the geographical and functional distribution of members on committees. (*j*) The Board has a continuing concern for AAEA's financial situation. One possible solution lies in reducing services or increasing membership. For more than twenty years the dues were low, and individuals had few questions about being members. With increased dues, the question is now "what is there in it for me." The AAEA has been providing collective services, but now greater professional specialization leads to a need to provide specialized selective services. Not only will greater systematic effort be made in membership recruiting in cooperation with the regional associations but effort will be made to increase the attractiveness of AAEA membership, partially through limitation of AAEA services to active members. In implementing this policy, the Board has decided that assignments to committees will be limited to members, higher registration fees for annual meetings will be charged for nonmembers, the privilege of giving contributed papers will be limited to members, and the privilege of giving invited papers and addresses will be limited, in general, to members. In addition, committees are working on new services to enhance and/or maintain members professional capacity. Hopefully, within the next three to five years improved services will be available for members.

7. No old business was noted.

8. New business items were requested. (*a*) Hildreth reported as secretary-treasurer of the International Agricultural Economics Association that over 600 attended the meetings in Kenya, with 80 from the United States. The next meeting will be in

Baniff, Canada, in September 1979. (*b*) Hildreth presented a resolution thanking Pennsylvania State University and its staff for being an excellent host, with a request that it be printed in the *Journal* and copies be sent to appropriate personnel of the university. (*c*) Bonnen announced the dates and sites of future meetings: 31 July–3 August 1977 at Town and Country Hotel, San Diego, California, and 6–9 August 1978 at Virginia Polytechnic Institute and State University, Blacksburg, Virginia. (*d*) Bonnen thanked Redman for his assistance as secretary-treasurer, Tomek as editor, Howard Robinson and Glenn Heitz as retiring directors, James Nielson as past president, and all who assisted in various ways. He then turned the chair over to Kenneth R. Farrell, who became president. (*e*) Farrell congratulated Bonnen on developing a systematic approach to committee structure and assignments and expressed his personal appreciation to Bonnen for his contributions to the AAEA. (*f*) In the form of announcements, Farrell indicated that the affairs of the AAEA will be as open as possible, does not plan to appoint a large number of committees and will indicate most chairmen in his presidential letter scheduled for October, announced the appointment of the nominating committee of which James T. Bonnen will be chairman (all suggestions should be sent to Bonnen or any committee member by 10 December) announced that all nominations for fellows should be sent to the secretary-treasurer by 1 December, announced that a new editor will be named and asked for suggestions, described San Diego as being a good meeting place and asked for suggestions for topics and speakers, and announced that the next Board meeting will be in late December or early January 1977.

8. Meeting adjourned at 10:05 a.m.

Respectfully submitted,
John C. Redman
Secretary-Treasurer

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American Agricultural Economics Association

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Past-President /James T. Bonnen, Michigan State University

15 JUL 1977

Directors

Wallace Barr, Ohio State University
Richard T. Crowder, Pillsbury Co.
Sylvia Lane, University of California, Davis
Fred A. Mangum, North Carolina State University
Philip M. Raup, University of Minnesota
B. F. Stanton, Cornell University

Objective

The AAEA seeks to further the systematic development of knowledge of agricultural economics in order to improve agriculture and agriculture's contribution to the general economy. The activities of the AAEA include:

—publishing the *American Journal of Agricultural Economics;*
—planning and conducting two annual meetings of the membership;
—sponsoring annual awards for outstanding extension programs, distinguished teaching, and outstanding research;
—recognizing outstanding agricultural economists through a fellows program;
—supporting a literature retrieval system in cooperation with the U.S. Department of Agriculture;
—publishing periodically a biographical directory of the AAEA's members;
—supporting an employment registry for agricultural economists in cooperation with the U.S. Department of Labor.

Membership and Subscriptions

Membership in the AAEA is open to individuals having a professional interest in agricultural economics. Dues, payable at the beginning of each calendar year, are as follows: regular members, $25, senior members, $12.50, and junior members, $12.50. Senior membership is open to persons, upon written request, who are sixty-five years of age or older and have retired from active professional work. Junior membership is for students and is limited to three years; students should use application forms available from and signed by the head of the department in which they are studying. Members receive this *Journal*.

The subscription rate for institutions and nonmembers is $35 per year. Individual issues of this *Journal* are $10.00.

Payment of membership dues, correspondence regarding subscriptions, orders for individual copies of the *Journal,* changes in address, or inquiries about the general affairs of the AAEA should be sent to John C. Redman, Secretary-Treasurer, American Agricultural Economics Association, Department of Agricultural Economics, University of Kentucky, Lexington, Kentucky, 40506.